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Development Document for Effluent Limitations Guidelines and Standards for the Coil Coating Point Source Category: Canmaking Subcategory

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Proposed

PB83-198598

Coil Coating

Point Source Category

(Canmaking Subcategory)

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Ernst P. Hall, Mary L. Belefski, and Jeffery D. Denit.

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Pursuant to Sections 301, 304, 306, 307, and 501 of the Clean Water Act, EPA has collected and analyzed data for plants in the Canmaking Subcategory of the Coil Coating Point Source Category. There are no existing national effluent limitations or standards for canmaking. This document and the administrative record provide the technical basis for proposing effluent limitations for existing direct dischargers, standards for new source direct dischargers, and pretreatment standards for new and existing indirect dischargers. The regulation of canmaking is included in the coil coating category because the materials processed, processes used, and wastewater characteristics are generally similar to those in coil coating.

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DEVELOPMENT DOCUMENT
for
Effluent Limitations Guidelines and Standards
for the
CANMAKING SUBCATEGORY
# of the
COIL COATING
POINT SOURCE CATEGORY

Frederic A. Eidsness, Jr.
Assistant Administrator
Office of Water

Steven Schatzow, Director
Office of Water Regulations and Standards

Jeffery D. Denit, Director
Effluent Guidelines Division

Ernst P. Hall, P.E., Chief
Metals and Machinery Branch

Mary L. Belefski
Project Officer

March, 1983

U.S. Environmental Protection Agency
Effluent Guidelines Division
Office of Water Regulations and Standards
Washington, D.C. 20460

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SECTION I

SUMMARY AND CONCLUSIONS

Pursuant to Sections 301, 304, 306, 307, and 501 of the Clean Water Act, EPA has collected and analyzed data for plants in the Canmaking Subcategory of the Coil Coating Point Source Category. There are no existing national effluent limitations or standards for canmaking. This document and the administrative record provide the technical basis for proposing effluent limitations for existing direct dischargers, standards for new source direct dischargers, and pretreatment standards for new and existing indirect dischargers. The regulation of canmaking is included in the coil coating category because the materials processed, processes used, and wastewater characteristics are generally similar to those in coil coating.

Canmaking covers all of the manufacturing processes and steps involved in the manufacturing of various, shaped metal containers which are subsequently used for storing foods, beverages and other products. Two major types of cans, seamed and seamless, are manufactured.

Subcategorization

The subcategory was studied for further subcategorization. In the manufacture of seamless cans, oil is used frequently as a lubricant during the forming of the seamless body and must be removed before further processing can be performed. Typically, this is accomplished by washing the can body in a continuous canwasher using water based cleaners. This step is followed by metal surface treating steps to prepare the can for painting.

In the manufacture of seamed (welded, clinched or soldered) cans, can ends, can tops and seamless cans from coated (e.g., coil coated) stock, no oil is used and the cans do not need to be washed after forming. Because no process wastewater is generated from these canmaking process segments they are excluded from regulation.

After study of all processes used in canmaking, EPA determined that no further subcategorization of Canmaking is required, and a single set of regulatory numbers is proposed for all wastewater generating canmaking facilities. The production normalizing parameter is the number of cans manufactured.

Data

Data collection for this subcategory focused on wet processes associated with canmaking. The technical data base includes information from 21 companies representing about 100 manufacturing sites. In addition to the data collection effort for this study, supplemental data were obtained from NPDES permit files and engineering studies on treatment technologies used in this and other categories with similar wastewater characteristics.

Pollutants or pollutant parameters generated in canmaking wastewaters are (1) toxic metals -- chromium, and zinc; (2) toxic organics listed as total toxic organics (TTO) (TTO is the sum of all toxic organic compounds detected) (3) nonconventional pollutants -- aluminum, fluoride, and phosphorus; and (4) conventional pollutants -- oil and grease, TSS, and pH. Because of the toxic metals present, the sludges generated during wastewater treatment generally contain toxic metals.

EPA identified both actual and potential control and treatment technologies (including in-process and end-of-process technologies). The Agency analyzed historical and newly generated data on the performance, operational limitations, and reliability of these technologies. Current wastewater treatment systems in the subcategory range from no treatment to a sophisticated physical chemical treatment combined with water conservation practices. EPA considered the impacts of these technologies on air quality, solid waste generation, water scarcity, and energy requirements.

No treatment equipment was reported in place at 8 canmaking plants. Oil removal equipment for skimming, chemical emulsion breaking or dissolved air flotation is in place at 53 canmaking plants, 7 plants have chromium reduction systems, 29 canmaking plants have pH adjustment systems without settling, 28 plants indicate they have equipment for chemical precipitation and settling, 10 plants have filtration equipment in place, 1 plant has ultrafiltration, and 1 plant has reverse osmosis equipment in place.

The performance of the treatment systems in place at all canmaking plants is difficult to assess because EPA has received a limited amount of canmaking effluent data. Additionally, some plants have equipment in place which they are not operating because existing requirements can be achieved without operation of treatment equipment. Consequently, treatment performance is transferred from other categories and subcategories which treat similar wastewaters.

For the subcategory, in general, there is no significant difference between the pollutants generated by direct or indirect dischargers or in the degree of treatment employed; several indirect dischargers have the same treatment equipment in-place as the direct dischargers. The degree of treatment equipment operation is primarily dependent upon the existing requirements. Section V of this document further evaluates the treatment systems in place and the effluent data received.

Treatment Costs

The Agency estimated the costs of each control and treatment technology using a computer program based on standard engineering cost analysis. Unit process costs were derived by applying canmaking data and characteristics to each treatment process (i.e., metals precipitation, sedimentation, mixed-media filtration, etc.). Costs were developed for model plants having one to six "normal" canmaking lines. Costs were estimated for each plant based on the number of canmaking lines and treatment equipment in place and individual plant costs summed to develop total costs for the subcategory. The Agency then evaluated the economic impacts of these costs.

Regulation

On the basis of these factors, EPA identified and classified various control and treatment technologies as BPT, BAT, BCT, NSPS, PSES, and PSNS. The proposed regulation, however, does not require the installation of any particular technology. Rather, it requires achievement of effluent limitations equivalent to those achieved by the proper operation of these or equivalent technologies.

Except for pH requirements, the effluent limitations for BPT, BAT, BCT, and NSPS are expressed as mass limitations -- a mass of pollutant per unit of production (number of cans). They were calculated by combining three figures: (1) treated effluent concentrations determined by analyzing control technology performance data; (2) production-weighted wastewater flow for the subcategory; and (3) any relevant process or treatment variability factor (e.g., mean versus maximum day). This basic calculation was performed for each regulated pollutant or pollutant parameter in the subcategory.

Because flow reduction is a significant pollutant reduction technology for this subcategory, mass based limitations and standards are necessary to ensure application and implementation of the model or equivalent technology. Pretreatment standards -- PSES and PSNS-- are also expressed as mass limitations rather than concentration limits to ensure that the effluent reduction in the total quantity of pollutant discharges resulting from the model treatment technology, which includes flow reduction, is realized.

The end-of-pipe treatment technology available for this subcategory and used as the basis for the proposed regulation include in-process water use reduction, and end-of-pipe technologies: oil removal by dissolved air flotation and emulsion breaking, chromium reduction and cyanide precipitation when necessary, and lime and settle technology to remove other pollutants.

BPT - The proposed limitations are based on wastewater flow normalization with chromium reduction and cyanide removal when required, emulsion breaking, dissolved air flotation, hydroxide precipitation and sedimentation. The more significant pollutants found in the wastewaters of the canmaking subcategory and regulated under BPT include chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS and pH. Sections VII and IX of this document explain the derivation of treatment effectiveness data and the calculation of BPT limitations based on water reuse in the canwasher and end-of-pipe oil removal plus lime and settle treatment.

Compliance with BPT limitations will result in direct dischargers removing (from raw waste) 4,415 kg/yr of toxic pollutants and 7.31 million kg/yr of other pollutants at a capital cost (1982 dollars) of $1.0 million and a total annual cost of $0.45 million including interest and depreciation.

BAT - Proposed BAT limitations are based on BPT level treatment (chromium reduction and cyanide removal when required, emulsion breaking, dissolved air flotation, hydroxide precipitation and sedimentation) with the addition of in-process flow reduction to reduce the discharge of toxic pollutants to the environment. The principal in-process water reduction technology is the use of a countercurrent cascade rinse in the canwasher. This technology is expected to reduce the total discharge flow by 67.5 percent.

Six plants presently meet the flow basis and 12 plants have the BAT treatment equipment in place. Additionally, the Agency believes that industry will install BAT technology equipment rather than installing BPT and upgrading it to BAT. Implementation of these BAT limitations will remove an estimated 4,633 kg/yr of toxic pollutants and 7.33 million kg/yr of other pollutants (from raw wastewater) at a capital cost of $0.68 million and a total annual cost of $0.42 million. The incremental effluent reduction benefits of BAT above BPT are the removal annually of 218 kg of toxic pollutants and 20,000 kg of other pollutants.

The pollutants regulated under BAT include chromium, zinc, aluminum, fluoride, and phosphorus.

NSPS - Proposed NSPS is based on the BAT end-of-pipe technology and flow reduction achieved by the installation of an extended multi-stage canwasher or its equivalent. This technology includes at least three additional stages for using countercurrent rinses and recirculation of rinses to minimize wastewater generation. This reduces total discharge flow by over 90 percent when compared to raw waste discharge. Assuming a new plant installs six production lines, the investment costs would be $0.97 million and annual costs would be $0.55 million. Pollutant removals would be 28,272 kg/yr for toxics and 44.04 million kg/yr for other regulated pollutants above raw wastewater.

The pollutants regulated under NSPS include chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS, and pH.

PSES - PSES is equivalent to BAT.

Implementation of PSES will remove an estimated 47,255 kg/yr of toxic metals pollutants and 75 million kg/yr of other pollutants (from raw waste) at a capital cost of $27.6 million and a total annual cost of $16.7 million.

The pollutants regulated in the canmaking subcategory under PSES include chromium, zinc, aluminum, fluoride, phosphorus and Total Toxic Organics (TTO). As discussed previously, there are toxic organics associated with lubricants used in the canmaking subcategory. Given the mix of toxic organic pollutants found in these wastestreams, and the fact that they may pass through POTW, the Agency proposed a pretreatment standard for TTO to control these pollutants. The proposed TTO standard is based on the application of oil and grease removal technology which achieves the same removal of TTO as the BCT model treatment technology.

PSNS - The Agency is proposing PSNS based on the same treatment technology as NSPS. The pollutants regulated under PSNS include chromium, zinc, aluminum, fluoride, phosphorus, and TTO.

BCT - BCT is not an additional limitation but replaces BAT for the control of conventional pollutants. For the canmaking subcategory, EPA has determined that the BPT end-of-pipe technology sequence with added flow reduction (BCT technology) is capable of removing significant amounts of conventional pollutants. The Agency compared the cost of removing conventional pollutants using the BCT technology with the costs of achieving comparable treatment in a POTW. Using the newly revised proposed BCT methodology, the result of this comparison indicates the cost for this removal is (-) $1.39 per pound, which is substantially less than the proposed POTW benchmark of $0.27 per pound. Because BCT technology is less costly than BPT technology the second phase of the cost test will also show a negative value. The application of BCT technology above BPT is accepted, and BCT limitations are established based on this technology for oil and grease, TSS, and pH. The lesser cost of BCT technology is due to the reduced wastewater flow and resultant reduction in treatment equipment size.

SECTION II

RECOMMENDATIONS

1. EPA has added a fourth subcategory to the coil coating category for the purpose of effluent limitations and standards. The fourth subcategory is: Canmaking

2. The following effluent limitations are proposed for existing sources:

Subcategory D - Canmaking

(a) BPT Limitations

Pollutant or Pollutant Property	BPT Effluent Limitations Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	74.21	(0.163)	30.03	(0.066)
Zn	235.01	(0.517)	98.95	(0.217)
Al	803.98	(1.768)	328.66	(0.723)
F	10513.65	(23.130)	4664.88	(10.262)
P	2950.89	(6.491)	1206.86	(2.655)
O&G	3534.00	(7.774)	2120.40	(4.664)
TSS	7244.70	(15.938)	3534.00	(7.774)
pH	within the range of 7.5 to 10 at all times			

(b) BAT Limitations

Pollutant or Pollutant Property	BAT Effluent Limitations Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	24.10	(0.053)	9.75	(0.021)
Zn	76.34	(0.167)	32.14	(0.070)
Al	261.17	(0.574)	106.76	(0.234)
F	3415.30	(7.513)	1515.36	(3.333)
P	958.58	(2.108)	392.04	(0.862)

3. The following effluent standards are being proposed for new sources:

Subcategory D - Canmaking

New Source Performance Standards

Pollutant or Pollutant Property	NSPS Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	5.88	(0.013)	2.38	(0.005)
Zn	18.62	(0.041)	7.84	(0.017)
Al	63.7	(0.140)	26.04	(0.057)
F	833.0	(1.833)	369.60	(0.813)
P	233.8	(0.514)	95.62	(0.210)
O&G	280.0	(0.616)	168.0	(0.370)
TSS	574.0	(1.263)	280.0	(0.616)
pH	within the range of 7.5 to 10 at all times			

4. The following pretreatment standards are proposed for existing sources and new sources:

(a) Pretreatment Standards for Existing Sources

Pollutant or Pollutant Property	PSES Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	24.10	(0.053)	9.75	(0.021)
Zn	76.34	(0.167)	32.14	(0.070)
Al	261.17	(0.574)	106.76	(0.234)
F	3415.30	(7.513)	1515.36	(3.333)
P	958.58	(2.108)	392.04	(0.862)
TTO	18.36	(0.040)	8.61	(0.009)
O&G (for alternate monitoring)	2353.	(5.177)	1148.0	(2.526)

(b) Pretreatment Standards for New Sources

Pollutant or Pollutant Property	Maximum for any one day		PSNS Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	5.88	(0.013)	2.38	(0.005)

Zn	18.62	(0.041)	7.84	(0.017)
Al	63.7	(0.140)	26.04	(0.057)
F	833.0	(1.833)	369.60	(0.813)
P	233.8	(0.514)	95.62	(0.210)
TTO	4.48	(0.010)	2.10	(0.005)
O&G (for alternate monitoring)	280.0	(0.616)	168.0	(0.370)

5. The following effluent limitations are proposed for best conventional pollutant control technology:

Best Conventional Pollutant Control Technology

Pollutant or Pollutant Property	BCT Effluent Limitations Maximum for any one day		BCT Effluent Limitations Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
O&G	1148.00	(2.526)	688.80	(1.515)
TSS	2353.4	(5.177)	1148.00	(2.526)
pH	within the range of 7.5 to 10 at all times			

6. EPA is considering establishing effluent limitations and standards based on an alternative end-of-pipe treatment technology which would use polishing filtration as a final step to be added for all existing source and new source treatment.

7. The following effluent limitations and standards are being considered for existing sources:

Subcategory D - Canmaking

BAT Limitations and PSES

Pollutant or Pollutant Property	BAT and PSES Maximum for any one day		BAT and PSES Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	21.23	(0.047)	8.61	(0.019)
Zn	58.54	(0.129)	24.10	(0.053)
Al	173.92	(0.383)	71.17	(0.157)
F	2278.78	(5.013)	1010.24	(2.222)
P	642.88	(1.414)	264.04	(0.581)

8. The following effluent standards are being considered for new sources and PSES:

Subcategory D - Canmaking

NSPS and PSNS

Pollutant or Pollutant Property	NSPS and PSNS Maximum for any one day		NSPS and PSNS Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	5.18	(0.011)	2.10	(0.005)
Zn	14.28	(0.031)	5.88	(0.013)
Al	42.4	(0.093)	17.36	(0.038)
F	555.8	(1.223)	246.4	(0.542)
P	156.8	(0.345)	64.40	(0.142)
O&G	140.0	(0.308)	140.0	(0.308)
TSS	210.0	(0.462)	168.0	(0.370)
pH	within the range of 7.5 to 10 at all times			

9. The following effluent limitations are being considered for best conventional pollutant control technology:

Best Conventional Pollutant Control Technology

Pollutant or Pollutant Property	BCT Effluent Limitations Maximum for any one day		BCT Effluent Limitations Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
O&G	574.00	(1.263)	574.00	(1.263)
TSS	861.00	(1.894)	688.80	(1.515)
pH	within the range of 7.5 to 10 at all times			

SECTION III

INTRODUCTION

LEGAL AUTHORITY

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101(a)). To implement the Act, EPA was to issue effluent limitations, pretreatment standards, and new source performance standards for industry dischargers.

The Act included a timetable for issuing these standards. However, EPA was unable to meet many of the deadlines and, as a result, in 1976, it was sued by several environmental groups. In settling this lawsuit, EPA and the plaintiffs executed a court-approved "Settlement Agreement." This Agreement required EPA to develop a program and adhere to a schedule in promulgating effluent limitations guidelines, new source performance standards and pretreatment standards for 65 "priority" pollutants and classes of pollutants, for 21 major industries. See Natural Resources Defense Council, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), modified, 12 ERC 1833 (D.D.C. 1979) modified by orders dated August 25 and October 26, 1982.

Many of the basic elements of this Settlement Agreement program were incorporated into the Clean Water Act of 1977. Like the Agreement, the Act stressed control of toxic pollutants, including the 65 "priority" pollutants. In addition, to strengthening the toxic control program, Section 304(e) of the Act authorizes the Administrator to prescribe "best management practices" (BMP) to prevent the release of toxic and hazardous pollutants from plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

GUIDELINES DEVELOPMENT SUMMARY

These effluent limitations and standards were developed from data obtained from previous EPA studies, literature searches, and a plant survey and evaluation program. This program was carried out in 1978-79 with followup work in 1982, and detailed the subcategory based primarily on 1981 data. This information was then catalogued in the form of individual plant summaries describing processes performed, production rates, raw materials utilized, wastewater treatment practices, water uses and wastewater characteristics.

In addition to providing a quantitative description of the canmaking subcategory, this information was used to determine if the characteristics of the subcategory as a whole were uniform and thus amenable to one set of effluent limitations and standards. The characteristics of the plants, manufacturing processes, and process wastewater generation and discharge were evaluated to determine whether additional subcategories were necessary. The subcategorization process is discussed in Section IV.

To supplement existing data, the Agency sent a data collection portfolio (dcp) under authority of Section 308 of the Federal Water Pollution Control Act, as amended, to each known canmaking company. Additional data were obtained through a sampling program carried out at selected sites. Sampling was conducted at 5 plants. The designated priority pollutants (65 toxic pollutants) and typical canmaking pollutants formed the basic list for sampling. Sampling and analysis were conducted to determine the source and quantity of the pollutant parameters.

EPA analyzed the available data to determine wastewater generation and mass discharge rates in terms of production for each production segment. In addition to evaluating pollutant generation and discharges, the Agency identified the full range of control and treatment technologies existing within or applicable to the canmaking subcategory. This was done considering the pollutants to be treated and the chemical, physical and biological characteristics of the pollutants. Special attention was paid to in-process technology such as the recovery and reuse of process solutions, the recycle of process water and the curtailment of water use.

Consideration of these factors enabled EPA to characterize various levels of technology as the basis for effluent limitations for existing sources based on BPT and BAT. Levels of technology appropriate for pretreatment of wastewater introduced into a POTW from both new and existing sources were also identified, as were the NSPS based on best demonstrated control technology processes, operating methods, or other alternatives (BDT) for the control of direct discharges from new sources. These technologies were considered in terms of demonstrated effluent performance relative to treatment technologies, pretreatment requirements, the total cost of application of the technology, the age of equipment and facilities involved, the processes employed, the engineering aspects of applying various types of control technique process changes, and non-water quality environmental impacts (including energy requirements).

Sources of Industry Data

Data on the canmaking subcategory were gathered from EPA studies, literature studies, inquiries to federal and state environmental agencies, raw material manufacturers and suppliers, trade association contacts and the canmaking manufacturers themselves. Additionally, meetings were held with industry representatives and the EPA. Known canmakers were sent a data collection portfolio (dcp) requesting specific information concerning each facility. Finally, a sampling program was carried out at 5 plants. The sampling program consisted of sampling and analysis at each facility to determine the presence of a broad range of pollutants and to quantify the pollutants present in canmaking wastewater. Specific details of the sampling program and information from the above data sources are presented in Section V.

Literature Study - Published literature in the form of books, reports, papers, periodicals, and promotional materials was examined. The most informative sources are listed in Section XV.

Plant Survey and Evaluation - The collection of data pertaining to canmaking facilities was a two-phased operation. First, EPA mailed a dcp to each company in the country known or believed to perform canmaking. This dcp included sections for general plant data, specific production process data, wastewater management process data, raw and treated wastewater data, wastewater treatment cost information, and priority pollutant information based on 1977 production records. Second, follow-up dcps were sent and returned with information based on 1981 production records. From this mailing and other contact with the industry, it is estimated that there are about 425 canmaking plants. The data base includes specific information from 21 companies representing about 100 manufacturing sites and general information from the industry trade association. However, plants manufacturing certain types of cans and can tops or ends discharge no process wastewater. The EPA data base contains information about 88 canmaking plants that discharge process wastewater. The 88 canmaking plants operate 224 canmaking lines. Most of these plants provided 1981 data.

Utilization of Industry Data

Data collected from the previously listed sources are used throughout this report in the development of a base for BPT and BAT limitations and NSPS and pretreatment standards. EPA studies as well as the literature provided the basis for subcategorization discussed in Section IV. Raw wastewater characteristics presented in Section V were obtained from the sampling program. Sampling was conducted because dcp information on wastewater characteristics was incomplete. Selection of pollutant parameters for control (Section VI) was based on both dcp responses and sampling results. These provided information on both the pollutants which the plant personnel felt were in their wastewater discharges and those pollutants specifically found in canmaking wastewaters as the result of EPA sampling. Based on the selection of pollutants requiring control and their levels, applicable treatment technologies were identified and described in Section VII of this document. Actual wastewater treatment technologies utilized by canmaking plants (as identified in the dcp responses and observed at the sampled plants) were also used to identify applicable treatment technologies. The costs of treatment (both individual technologies and systems) were based primarily on data from equipment manufacturers and are contained in Section VIII of this document. Finally, dcp data, sampling data and estimated treatment system performance are utilized in Sections IX, X, XI XII, and XIII (BPT, BAT, NSPS, pretreatment, and BCT respectively) in the selection of applicable treatment systems; the presentation of achievable effluent levels; and the presentation of actual effluent levels obtained for the canmaking subcategory.

DESCRIPTION OF THE CANMAKING SUBCATEGORY OF THE COIL COATING CATEGORY

Background

The subcategory covered by this document includes facilities which manufacture cans. Manufacturing operations may include forming, cleaning, chemically treating, and applying an organic coating to metal cans. The processing operations for making certain types of cans such as draw and iron (D&I) are somewhat similar to coil coating operations.

Historical

In 1819, William Underwood utilized a tinplated container, patented by Peter Durand in 1810, and a process for preserving food by boiling, developed by Nichols Appart in 1809, to manufacture the first commercial tin can in the United states. However, Gail Borden's introduction of canned condensed milk in 1853 was responsible for the widespread acceptance of the can as a food container.

Cans were initially handmade until 1890 when the Norton Brothers introduced the first completely automated canmaking machine. Many other inventions and innovations have since made can manufacturing a sophisticated process. By 1960, over 200 billion food cans, 10 billion beer and beverage cans and 4 billion other nonfood cans were sold. The development of the pop-top tab for beer and beverage cans in 1962 marked the entry of aluminum alloys, as major materials, into the canmaking industry. The manufacture of a two-piece (can body and top), drawn and ironed aluminum alloy can was perfected in 1963. This container offers many advantages such as lighter weight, recycling potential, corrosion resistance and no seam leakage. The two-piece can now accounts for about 92 percent of the beverage can market.

Product Description

The can manufacturing industry is included within the U.S. Department of Commerce, Bureau of the Census, Standard Industrial Classification (SIC) 3411 - Metal Cans. The canmaking process produces a wide variety of sizes and shapes of metal containers which are subsequently used for storing foods, beverages and other products (e.g., deodorant or aerosol cans). A metal can is a single-walled container constructed wholly of tinplate, terneplate, blackplate (including tin-free steel), waste plate, aluminum sheet or impact extrusions and designed for packaging products.

Description of Canmaking Processes

Canmaking operations include all of the manufacturing processes and steps involved in the manufacturing of various shaped metal containers which are subsequently used for storing foods, beverages and other products. Two major types of cans are manufactured: seamed cans and seamless cans. Can bodies and can tops are made on separate lines and frequently in different plants.

Can ends and tops are manufactured by stamping and forming sheet metal (frequently plated or coil coated stock) into appropriate contours. The can ends and tops do not require washing before shipment.

Seamed cans (primarily three-piece cans) are manufactured by forming a flat piece or sheet of metal into a container with a longitudinal or side seam which is crimped, welded, or soldered, and attaching formed ends to one or both ends of the container body. About 300 plants in the United States manufacture seamed cans.

Seamed can bodies are usually fabricated by wrapping the sheet metal body around a mandrel and locking the seam. The seam may be locked by soldering, welding, or clinching with a sealant in the joint. The body is then fitted with one or both ends (bottom and top). No process wastewater is generated from these processes.

Seamless cans consist of a can body formed from a single piece of metal and usually a top (or rarely two ends) that are formed from sheet metal and attached to the can body. Beverage cans and other long cans are produced by: drawing and ironing, commonly referred to as D&I; by drawing and redrawing; or by impact extrusion. Shallow cans, such as sardine cans, are produced by drawing or stamping methods. About 125 plants in the United States manufacture seamless cans. Can ends are always produced by a stamping operation.

Drawing and Ironing (D&I)

This process sequence is shown in Figures III-1 and III-2, (pages 21 and 22). Process steps are listed and detailed below:

1. Metal coils are uncoiled.
2. Lubricants are applied and the sheet is straightened.
3. A machine called a cupper cuts a circular blank from the metal and draws the blank into a cup. Scraps of metal are collected and baled for recycle.
4. Cups are fed into the body maker which redraws the cup to the final can diameter, irons the sides to lengthen the can by thinning the metal, and places an inverted dome in the can bottom.
5. The cans are trimmed to a uniform height.
6. The cans are cleaned and the metal surface is treated.
7. Coatings and decorations are applied to the cans.
8. The open end of the can is necked and flanged to receive the can top.

Lubrication - In the manufacture of seamless can bodies oil-water emulsions are used as lubricants, coolants, and carriers for metal fines that are generated in the canmaking process. For the D&I process sequence, different lubricants are used in the cupping and ironing steps. The cupping lubricant needs to be compatible with the residual rolling oil on the metal sheet. The redraw and D&I (or body maker) lubricants must be superior in cooling capacity. A single lubricant oil at different emulsion concentrations is sometimes used in both the cupper and body maker. This eliminates cross contamination, improves productivity, and increases lubricant batch life by facilitating reclaim and re-use.

Canmaking lubricants are based on mineral oils or synthetic oils together with solubilizing or emulsifying agents such as fatty acids, and soaps. In the canwasher, emulsified oils - those suspended in solution that will not separate by settling - are "broken" to produce free oils which can be separated from the wastewater by simple treatment means such as settling, separation, and skimming. Emulsified oils are typically broken through the use of coalescing agents.

Cleaning - Cans must be cleaned to remove residual lubricant oils before decoration or coating. Frequently, hot water is used in the prewash stage, followed by an acid cleaning step. The acids frequently used are sulfuric and hydrofluoric acids and may be modified by addition of a detergent. The sulfuric acid aids removal of the oil, and the hyrofluoric acid etches the aluminum lightly and releases imbeded aluminum particles from the can body. In other cases hot water and a buffered alkaline cleaner may be used for the washing step. This washing operation is carried out in a canwashing machine which combines this and several other operations.

Surface Treatment - After the can body is cleaned and rinsed it is prepared to receive an organic coating such as decorative paint or lacquer. For aluminum cans this preparation may be a conversion coating such as phosphate or chromate. The basic objective of the conversion coating process is to improve adhesion of the paint film. The conversion coating is chemically and physically bonded into the basis metal and provides a smooth and chemically inert surface for the paint.

Phosphate coatings are formed in the metal surface, incorporating metal ions into the surface to to create a coating which is integrally bonded into the basis metal. Phosphating solutions consist of metal phosphates dissolved in carefully balanced solutions of phosphoric acid. Today, zirconium and titanium are commonly used in formulations for canmakers although other metals could be substituted. Accelerators speed up film formation and prevent the polarization effect of hydrogen on the surface of the metal. In some formulations an etchant is used to remove the aluminum oxide film, allowing direct bonding of the film to the metal. After phosphating, the can is passed through a hot water rinse to remove excess acid and un-reacted products, thereby stopping the conversion coating reaction.

Chromate conversion coatings for aluminum may be applied from acidic or basic solutions. The acid solutions usually contain one chromium salt, such as sodium chromate, or chromic acid and a strong oxidizing agent such as hydrofluoric acid or nitric acid. The exact mechanisms that cause formation of the film are not completely understood. The final film usually contains both products and reactants, and waters of hydration. Chromate films are formed by the chemical reaction of hexavalent chromium with a metal surface in the presence of "accelerators". The hexavalent chromium is partially reduced to trivalent chromium during the reaction, with a concurrent rise in pH. These reactions form a complex mixture consisting of hydrated basic chromium chromate complexes, hydrous oxides of both chromium and the basis material ions, varying quantities of reactants, reaction products and water of hydration, as well as the associated ions of the particular system. The presence of hexavalent chromium is essential, but its concentration in chromating solutions can vary widely with limited effects as compared to the effects of fluctuation in pH.

Canwasher - Canwashers are the primary source of process wastewater in the canmaking process. As discussed above, several operations are performed in a canwasher. The simplest or "classic" version in common use in the canmaking industry consists of five stages to which a sixth, prewash, stage is frequently added, as shown in Figure III-3 (page 23): prewash, acid clean, rinse, surface treatment, rinse, and DI (deionized water) rinse. The acid cleaner is added to the second stage and the surface treatment chemicals are added to the fourth stage.

A more advanced canwasher shown in Figure III-4 (page 24) which cuts water use significantly may be used. Water use reduction is achieved by countercurrent cascade rinsing following the cleaning and surface treatment stages. Separate rinse steps with countercurrent flow are used within each rinse stage.

More than half of the canmaking plants surveyed practice reuse of water within the canwasher. Techniques vary, but in one version (see Figure III-3, page 23) the fresh water is introduced into the rinse following surface treatment (Stage 5). From the fifth stage the water is introduced into the rinse following acid cleaning (Stage 3), and from there into the prewash (Stage 1) before discharge. The deionized water in the final stage is continuously recirculated through the deionization unit. Makeup water to replace drag out and evaporation is added at the deionization unit. Regeneration water is discharged.

Final Can Preparation - After cleaning and chemical treatment in the wash line, the cans are dried in an oven. The cans are automatically placed onto a moving belt which takes the cans through the drying oven to the decorating line. The first step in the decoration process is often an application of a base coat followed by drying in an oven. Following this, the cans are imprinted with up to four colors. The design is applied by simultaneously spinning the print roller and the can. Immediately following that, a coat of lacquer may be applied to the bottom of the can, which then goes to a drying oven. Next the inside surface of the can is coated by spraying a food grade lacquer on the inside surface of the can and again the can is conveyed to an oven for drying.

The cans are prepared to receive a top by necking and flanging the open end of the can. The finished cans are then tested for leaks, palletized and shipped.

Draw and Redraw

This process is sometimes mistakenly called stamping. A metal blank is held between a pair of draw rings and is forced to flow over a punch to form a cup as shown in Figure III-2 (page 22). If a deeper part is required, it may be successively redrawn over progressively smaller diameter punches. Parts produced by this method can have greater depths than those produced by stamping because the movement of the metal can be controlled.

The draw and redraw process may use either coated or plain stock. When coated stock is used the lubricant used is usually a light wax which is allowed to remain in the can and the can shipped without washing. Plain stock is lubricated before drawing and the lubricants are removed from the can either by washing or by solvent cleaning. Lubrication and canwashing are discussed above under Drawing and Ironing.

INDUSTRY SUMMARY

There are approximately 300 seamed can plants and 125 seamless can plants located throughout the United States and its territories. Of the 89 seamless can plants that generate wastewater, 81 are indirect dischargers, seven are direct dischargers and one plant does not discharge. Seamless cans account for approximately 92 percent of the beverage can market and 60 percent of total can shipments. Seamed cans make up a larger proportion of other can markets. Aluminum D&I cans account for about 73 percent of the seamless can group. Metal can shipments in 1980 totaled 87.9 billion units.

Total wastewater discharge from the canmaking subcategory is about 11.4 billion l/year with a discharge of an estimated 53,000 kg of toxic pollutants in its wastewaters every year.

There are no existing national effluent limitations and standards for this subcategory. Treatment technologies in-place range from none to a complete system incorporating ultrafiltration and reverse osmosis which both result in no discharge of wastewater. The amount of treatment equipment in place is mainly a function of local pretreatment requirements and enforcement.

INDUSTRY OUTLOOK

Although metal can shipments totaled 87.9 billion units in 1980, this was a 1.6 percent decline from 1979. With the U.S. economy experiencing severe dislocations, inflation and a general slowdown, losses occurred in all except four product categories--beer, soft drink, baby foods and seafoods. Beverage cans posted a modest gain of slightly more than 1 percent, with a total of 55.2 billion units--more than 62 percent of total can shipments. Beer can shipments increased 2.7 percent presummably because the hot summer of 1980 boosted demand. Soft drinks had a very slight increase from 1979 of 0.1 percent.

Two piece cans continued to dominate the beverage markets, accounting for 92 percent of shipments--98 percent in beer and 85 percent in soft drinks. Overall, two-piece cans now represent 60 percent of total can shipments.

TREATMENT IN PLACE

The canmaking industry has various end-of-pipe and in-process treatments already in place. Approximately ten percent of the plants have no treatment in place. The most common wastewater treatments in place as determined from dcp responses are listed below:

Treatment In Place	Percent of Plants
Chemical precipitation and settling	35
pH adjust	70
Filtration	10
Oil Removal	64

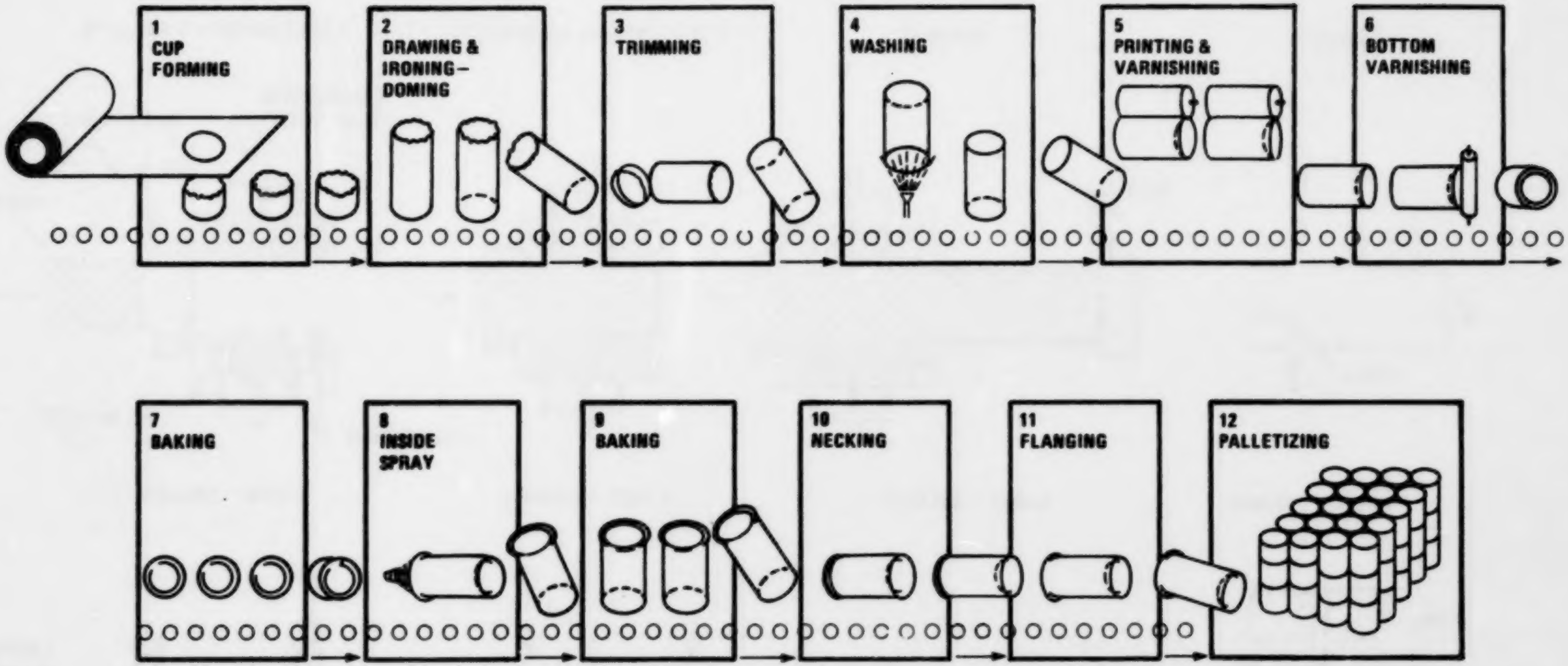
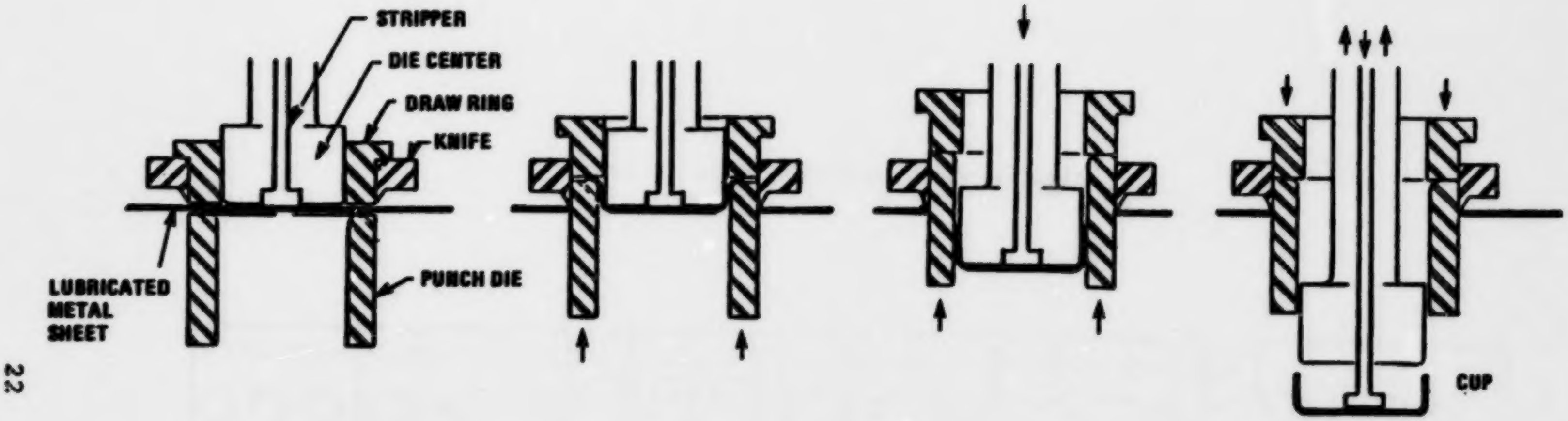
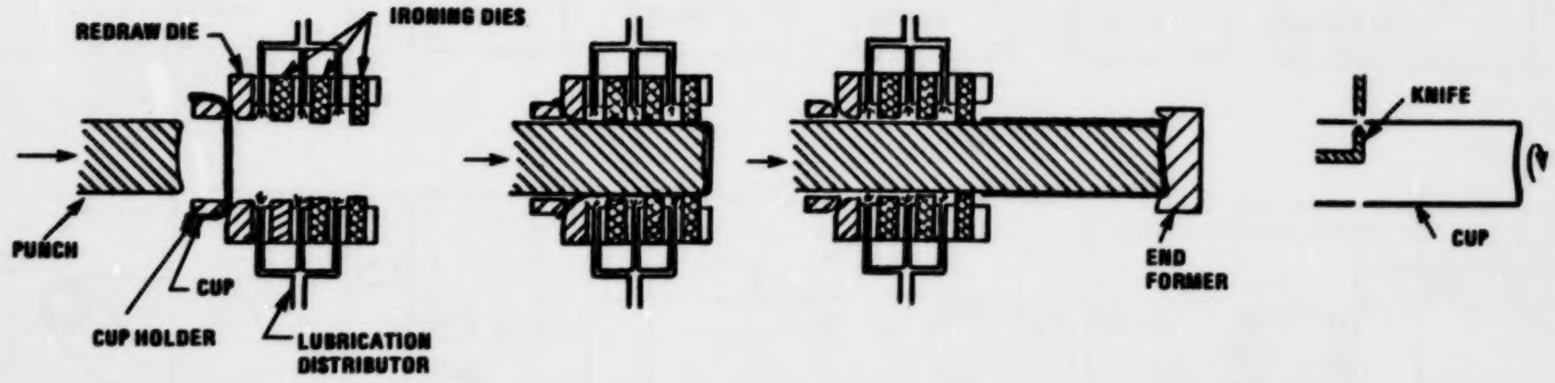

1 CUP FORMING
2 DRAWING & IRONING–DOMING
3 TRIMMING
4 WASHING
5 PRINTING & VARNISHING
6 BOTTOM VARNISHING
7 BAKING
8 INSIDE SPRAY
9 BAKING
10 NECKING
11 FLANGING
12 PALLETIZING

FIGURE III-1. PRODUCTION OF DRAW AND IRON CAN BODIES


STRIPPER
DIE CENTER
DRAW RING
KNIFE
LUBRICATED METAL SHEET
PUNCH DIE
CUP

CUPPING – STEP 1 CUPPING – STEP 2 CUPPING – STEP 3 CUPPING – STEP 4


REDRAW DIE
IRONING DIES
PUNCH
CUP
CUP HOLDER
LUBRICATION DISTRIBUTOR
END FORMER
KNIFE
CUP

DRAWING & IRONING STEP 1 DRAWING & IRONING STEP 2 DOMING TRIMMING

FIGURE III-2 DETAIL OF CAN DRAWING & IRONING

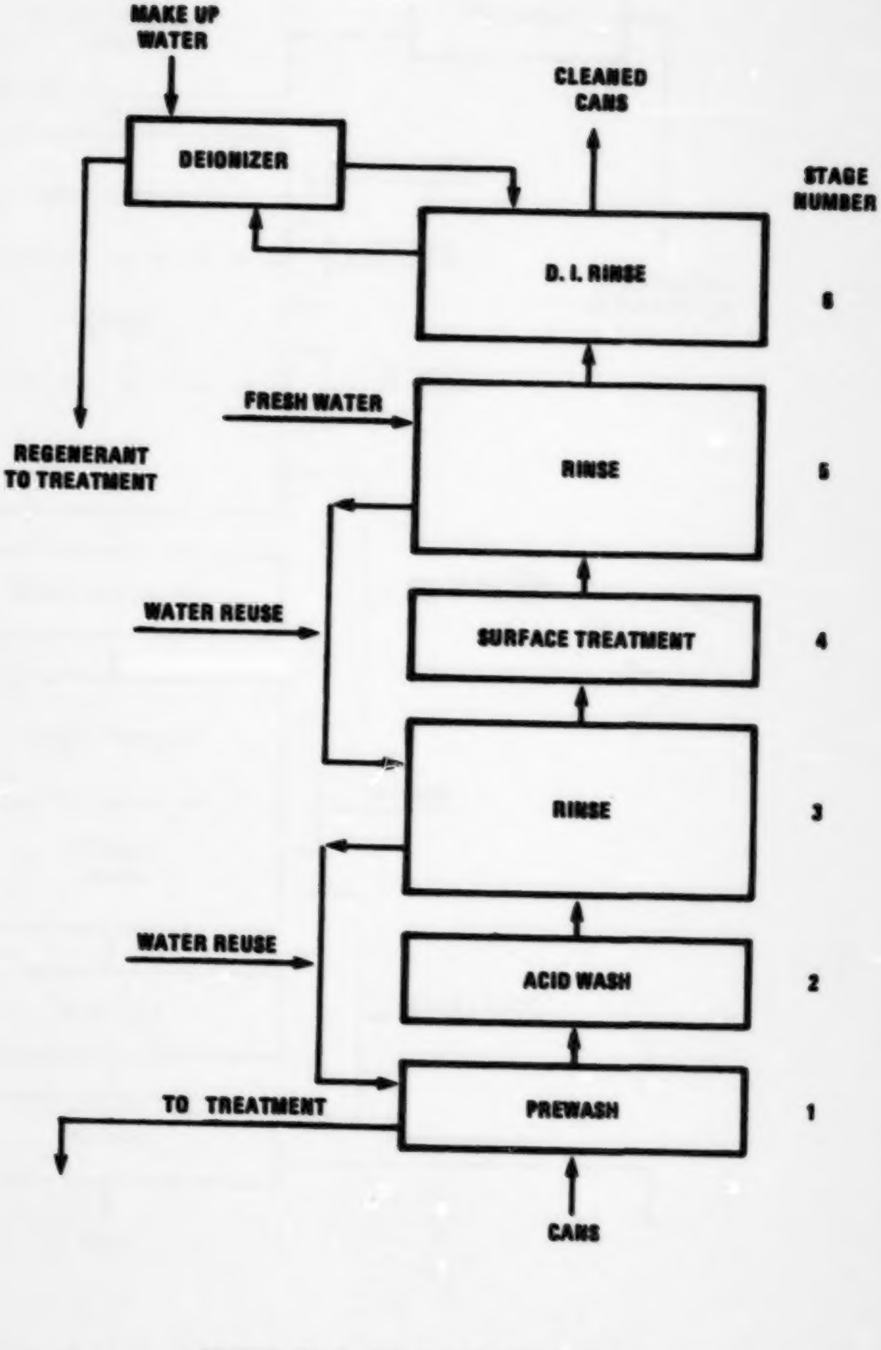

MAKE UP WATER
DEIONIZER
CLEANED CANS
STAGE NUMBER
D. I. RINSE
6
FRESH WATER
REGENERANT TO TREATMENT
RINSE
5
WATER REUSE
SURFACE TREATMENT
4
RINSE
3
WATER REUSE
ACID WASH
2
TO TREATMENT
PREWASH
1
CANS

FIGURE III-3. SIX STAGE CANWASHER

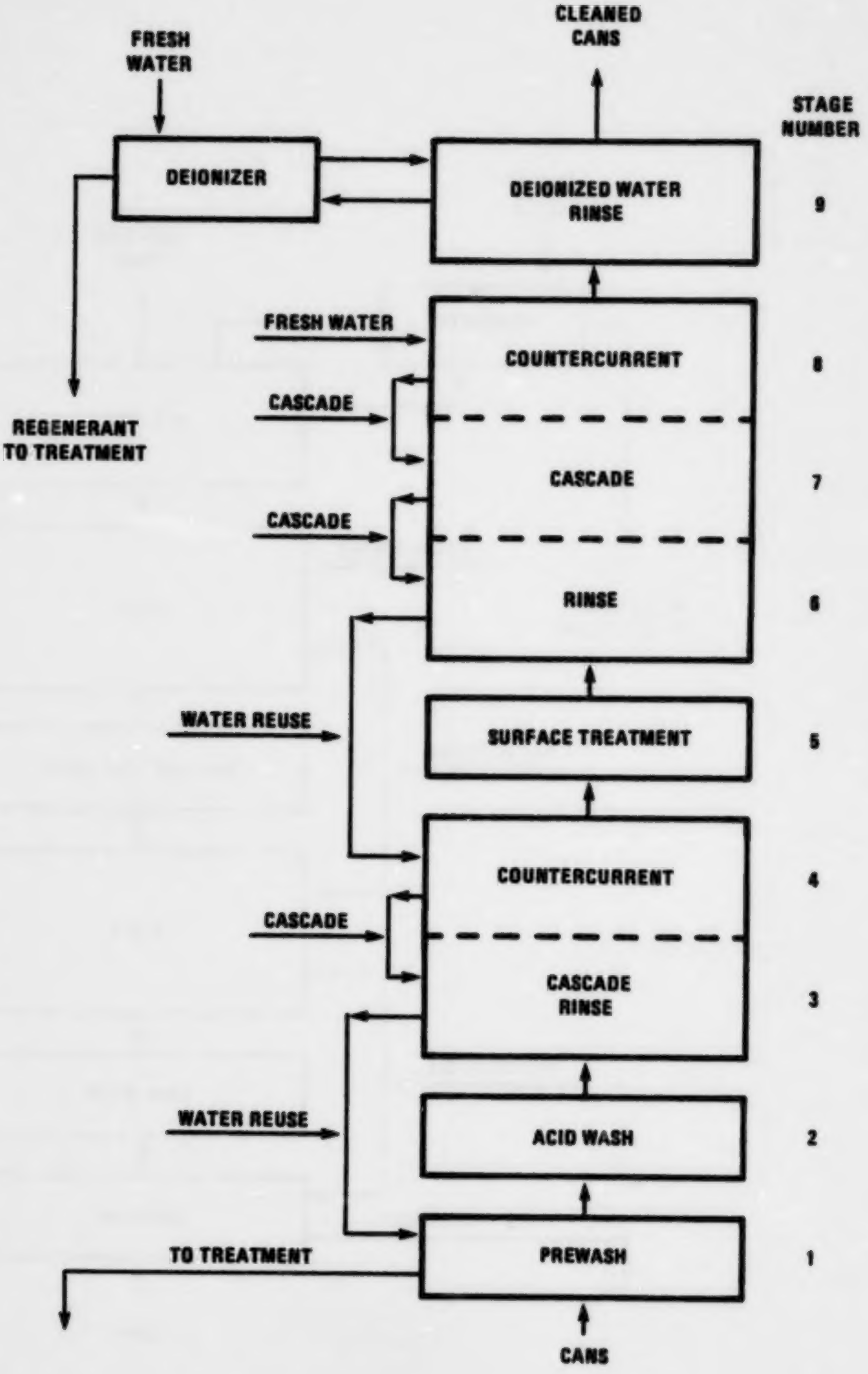

CLEANED CANS
FRESH WATER
STAGE NUMBER
DEIONIZER
DEIONIZED WATER RINSE
9
REGENERANT TO TREATMENT
FRESH WATER
COUNTERCURRENT
8
CASCADE
CASCADE
7
CASCADE
RINSE
6
WATER REUSE
SURFACE TREATMENT
5
COUNTERCURRENT
4
CASCADE
CASCADE RINSE
3
WATER REUSE
ACID WASH
2
TO TREATMENT
PREWASH
1
CANS

FIGURE III—4. EXTENDED MULTI-STAGE CANWASHER

SECTION IV

INDUSTRY SUBCATEGORIZATION

Subcategorization should take into account pertinent industry characteristics, manufacturing process variations, water use, wastewater characteristics, and other factors which are important in determining a specific grouping of industry segments for the purpose of regulating wastewater pollutants. Division of the category into subcategories provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. Effluent limitations and standards establish mass limitations on the discharge of pollutants and are applied, through the permit issuance process, to specific dischargers. To allow the national standard to be applied to a wide range of sizes of production units, the mass of pollutant discharge must be referenced to a unit of production. This factor is referred to as a production normalizing parameter and is developed in conjunction with subcategorization.

Division of the subcategory into segments provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. The selection of production normalizing parameters provides the means for compensating for differences in production rates among plants with similar products and processes within a uniform set of mass-based effluent limitations and standards.

SUBCATEGORIZATION BASIS

Factors Considered

For the purposes of subcategorizing canmaking EPA evaluated the following:

1. Manufacturing Processes
2. Water Use
3. Basis Material Used
4. Products Manufactured
5. Wastewater Characteristics
6. Water Pollution Control Technology and Treatment Costs
7. Solid Waste Generation and Disposal
8. Size of Plant
9. Age of Plant
10. Number of Employees
11. Total Energy Requirements (Manufacturing Process and Wastewater Treatment and Control)
12. Non-Water Quality Characteristics

13. Unique Plant Characteristics

A review of each of the possible subcategorization factors reveals that the processes performed and their use of water are the principal factors affecting wastewater characteristics of canmaking plants. Processes performed in canmaking include cupping, drawing and ironing, redrawing, trimming, washing, annealing, base coating, printing, interior coating, necking, flanging, can top stamping, welding, soldering, sealing and drying. Of these processes, those generating significant amounts of wastewater are washing, which includes rinses after cleaning and chemical treatment steps, and drawing and ironing, which use oil emulsified in water for lubricating and cooling the can material while it is being shaped. Some wastewater also may be generated by fume scrubbers used on drying ovens. The major source of pollutants in the wastewaters are the process chemicals including the lubricant and coolant oils. Other sources are the basis materials and the organic materials trapped by fume scrubbing. The other processes that do not generate wastewater were evaluated and are not considered for regulation. They are discussed in Section III of this document.

Canwashing generates virtually all of the wastewater discharged from canmaking. Canwashing removes oils and metal particles from the surface of cans and also removes cleaning and surface treatment chemical residues from the can surface. The basis materials washed were compared to determine whether the different basis materials should be separately subcategorized. DCP and sampling data indicate that wastewater flows from steel cans may vary but are similar to the flows for aluminum cans (see tables V-2 and V-3). This range of variance is not an adequate basis for separate subcategorization. Similarily as shown in Table V-7 (page 49) less toxic metals were found in the wastewater from steel cans. However, the level of oil and grease and presumably TTO for steel cans is similar to aluminum and treatable levels of toxic metals and nonconventional pollutants are generated by washing steel cans. Because these differences are small further subcategorization of cans that are washed is not appropriate. Canmaking is to be regulated as a single subcategory.

Subcategory Selection. Subcategorization primarily by water use and secondarily by production process used is the most logical method for further dividing canmaking because it focuses on the source of wastewaters. Other subcategorization bases considered, but not recommended, are presented in the following subsections along with the reasons why they are not as appropriate as the approach selected.

Basis Material Used

As discussed above, processes and wastewater characteristics are relatively similar for industry process segments that use different basis materials, therefore, further subcategorization for the basis materials used is not appropriate.

Products Manufactured

The products produced by the canmaking industry are metal containers used for storing foods, beverages, and other products. The cans are essentially the same and thus do not provide a basis for subcategorization.

Wastewater Characteristics

As discussed above, the constituents of wastestreams from those process segments of the industry that generate wastewater are relatively similar and are not an appropriate basis for further subcategorization.

Water Pollution Control Technology and Treatment Costs

The necessity for a subcategorization factor to relate to the raw wastewater characteristics of a plant automatically eliminates certain factors from consideration as potential bases for subdividing the industry. Water pollution control technology and treatment costs have no effect on the raw wastewater generated in a plant. The water pollution control technology employed at a plant and its cost are the result of a requirement to achieve a particular effluent level for a given raw wastewater load. It does not affect the raw wastewater characteristics.

Solid Waste Generation and Disposal

Physical and chemical characteristics of solid waste generated by the canmaking industry are determined by the process chemicals. Furthermore, solid waste disposal techniques may be identical for a wide variety of solid wastes and do not provide a sufficient basis for subcategorization.

Size of Plant

The nature of the processes for the canmaking subcategory are the same in all facilities regardless of size. The size of a plant is not an appropriate basis for subcategorization because the wastewater characteristics of a plant per unit of production are essentially the same for plants of all sizes when processing the same basis material. Thus, size alone is not an adequate basis for segmentation since the wastewater characteristics of plants depend on the type of products produced.

While size is not adequate as a technical segmentation parameter, EPA recognizes that the capital investment for installing wastewater control facilities may be greater for small plants relative to the investment in their production facilities than for larger plants. Consequently, the size distribution of plants was investigated during the development of limitations, and wastewater treatment technology recommendations were reviewed to determine if special considerations are required for small plants.

Age of Plant

While the relative age of a plant is important in considering the economic impact of a guideline, it is not an appropriate subcategorization basis because it does not reflect the fact that old plants may house equipment for seamless cans only, or they may house equipment for making both seamed cans and seamless can bodies. Since one type of operation generates wastewater and the other generates essentially no wastewater, the generation of process wastewater is not related to age of the plant.

Number of Employees

The number of employees in a plant does not directly provide a basis for subcategorization because the number of employees does not necessarily reflect the production or water use at any plant. Further, the rate of production depends on the process steps employed and the specific product manufactured. The amount of wastewater generated is related to the production rates, and the number of employees does not provide a definitive relationship to wastewater generation.

Total Energy Requirements

Total energy requirements were excluded as a basis for subcategorization primarily because of the difficulty in obtaining reliable energy estimates specifically for production and wastewater treatment. When energy consumption data are available, they are likely to include other energy requirements such as lighting, air conditioning, and heating as well as energy required to run the plant and treatment facility.

Non-Water Quality Aspects

Non-water quality aspects may have an effect on the wastewater generated in a plant. A non-water quality area such as air pollution discharges may be under regulation and water scrubbers may be used to satisfy such a regulation. This could result in an additional contribution to the plant's wastewater. However, it is not the prime cause of wastewater generation in canmaking, and is therefore not acceptable as an overall subcategorization factor.

Unique Plant Characteristics

Unique plant characteristics such as geographical location, space availability, and water availability do not provide a proper basis for subcategorization because they do not affect the raw wastewater characteristics of the plant. Process water availability may be a function of the geography of a plant and the price of water determines any necessary modifications to procedures employed in each plant. However, required procedural changes to account for water availability only affect the volume of pollutants discharged, not the characteristics of the constituents. Wastewater treatment procedures can be utilized in any geographical location.

A limitation in the availability of land space for constructing a wastewater treatment facility may affect the economic impact of an effluent limitation. However, in-process controls and rinse water conservation can be adapted to minimize the land space required for the end-of-process treatment facility. Often, a compact treatment unit can easily handle end-of-process waste if good in-process techniques are used to conserve raw materials and water.

Summary of Subcategorization

For this regulation, the Agency has determined that the principal factor affecting the wastewater characteristics of plants in the canmaking subcategory are water use and the manufacturing process employed. The manufacture of seamed cans, can ends and can tops and some seamless (draw-redraw) cans is accomplished without generating wastewater. These canmaking segments are not controlled by this regulation. Seamless cans made from aluminum or steel by the D&I Process and seamless cans made by the draw-redraw process which are washed are controlled by this regulation. Because the wastewater volume and waters of these cans that are washed are similar no further segmentation of the subcategory is necessary.

PRODUCTION NORMALIZING PARAMETER

The production normalizing parameter (PNP) is used to normalize wastewater and pollutant factors and allow limitations and standards to be applied across a variety of plant sizes and production rates. In considering the canmaking subcategory three possible PNP's were considered; area of metal processed, number of cans manufactured and mass (weight) of cans manufactured.

Canmaking operations, like most metal surfacing processes, are dependent on processed area. The amount of chemicals and other raw materials used and the amount of wastewater and wastewater pollutants is proportional to the surface area processed. For this reason surface area is the first production normalizing parameter (PNP) considered. However, surface area processed is not readily available from industrial production records, and this parameter was not selected as the PNP.

A direct measure of production -- number of cans -- was next considered. Because the number of cans of any size produced is directly related to surface area processed, and because most plants maintain records in terms of numbers of cans produced, it is considered to be the best production normalizing parameter for canmaking. The difference in can sizes as it relates to can surface area was evaluated. Twelve ounce cans comprise a very large fraction of the total beverage can output. Some sixteen ounce cans are produced as are eight and ten ounce cans. Sixteen ounce cans have about 29 percent more surface area than a twelve ounce can while eight ounce cans have proportionately less area. Since the other than twelve ounce cans are small volume items, they are manufactured in plants that mostly make twelve ounce cans and any slight difference in can area is not significant.

The weight of product manufactured was considered. However, because different basis materials are used within the subcategory, weight may vary significantly and was rejected from further considerations.

EPA has selected the number of cans produced as the production normalizing parameter.

SECTION V

Water Use and Wastewater Characterization

This section presents summaries and supportive data which describe and characterize canmaking water use and wastewater. Data collection and data analysis methodologies are discussed. Raw wastewater and final effluent constituents, treatment in place, and flow rates are presented for the subcategory.

INFORMATION COLLECTION

EPA collected information from a number of sources about the canmaking industry. Some existing information was available in the Agency including permits for canmaker who discharge to surface waters, and information that was collected concurrently by the Office of Air Quality Planning and Standards. EPA conducted a literature search to find pertinent published information about canmaking. Technical information was provided by industry representatives and the industry trade association. Information requests were sent to all known canmaking companies and also to several chemical suppliers. The greatest amount of wastewater data was collected during the sampling program.

The National Pollutant Discharge Elimination System (NPDES) permits for canmaking facilities which had a direct discharge stream were obtained from the Regional EPA offices. In some cases, the permits involved streams other than canmaking wastewaters. Some facilities directly discharge the cleaning wastewaters after treatment; but most plants discharge wastewaters to a Publicly Owned Treatment Works (POTW). The Agency was hoping to learn current industry practices for wastewater treatment; however, the information in the permits was insufficient for this purpose. The permits did not specify where the discharge streams originate and it was not possible to determine whether cooling water or other processes not under the canmaking category were included in the discharge. It also was not possible to relate the permit limitations to production, which precluded any analysis for effluent limitations except by concentration. For these reasons, the permit information has had very little impact on this study.

EPA conducted a literature search to obtain as much pertinent published material about the canmaking industry as possible. Information was collected on the processes used, the purpose of and theory behind each process, the chemicals used, the economics of the process, the methods of conserving water, and the methods of treating wastewaters from canmaking. Some of this informaton is summarized in Section III.

Industry representatives and the Can Manufacturers' Institute provided information during the development of this study.

PLANT DATA COLLECTION

Data requests were sent in 1978 to canmaking facilities during technical development of the Aluminum Forming Category. In 1982 canmakers who had responded to the 1978 request were asked to update their data and other selected canmakers were asked to supply data. The 1978 data collection effort collected information primarily about aluminum D&I canmaking and the selected data requests in 1982 were addressed primarily to manufacturers of steel cans. At the end of the 30 day response period, a follow up phone call was made to those establishments which had not responded. Information about the chemical constituents of some of the proprietary chemical baths used in canmaking was useful as a guide to the Agency on where to look for pollutants and what pollutants to expect.

In total, information on 89 canmaking facilities that generate process wastewater was received. These facilities operate about 224 canmaking lines. The number of canmaking lines was obtained from dcp information. The Agency obtained some usable information from each of the wastewater-generating canmaking facilities known to the Agency, and 92 percent supplied usable treatment in place data.

Processing of dcp Responses - Each dcp response was logged in and examined for claims of confidentiality. Information claimed to be confidential or proprietary was segregated from other information and was processed according to the EPA requirements for handling information claimed to be confidential. The dcp responses were interpreted individually and the most frequently used data transferred to a summary sheet for quick reference and evaluation. This included such data as company name, plant address, and name of the contact listed in the dcp; plant discharge status as direct (to surface water), indirect (to a POTW), or zero discharge; production process streams present, as well as the associated flow rates; production rate; operating hours; wastewater treatment, reuse, or disposal methods; the process chemicals and the type of oil used; treatment capital costs; and availability of pollutant monitoring data provided by the plant.

The calculated information derived from the dcp's were used throughout the study. Principal areas of application included the subcategory profile, evaluation of subcategorization, analysis of in-process treatment and control technologies, and determination of water use and discharge values for the conversion of pollutant concentration to mass loadings. Each facility was assigned a three digit identification number which is used throughout the study and this document for identification.

Selection of Plants for Sampling - Information from the dcp served as the primary basis for selection of plants for engineering and sampling visits in 1978 and 1979. The specific criteria used to select plants for visits included:

- Manufacturing processes that are representative of the industry as a whole.
- Operating wastewater treatment systems or water conservation methods.

Engineering visits were conducted at 7 facilities to supplement dcp information and to review plants for possible sampling visits.

A minimum of three days of sampling was performed for each of the four seamless aluminum can body manufacturing plants and one day of sampling for the seamless steel can body manufacturing plant. The sampling points at each sampled plant were developed, after an engineering plant visit.

SAMPLING PROGRAM

Methodology - Prior to sampling visits, all available data, such as plant layouts and diagrams of the production processes and wastewater treatment facilities were gathered and reviewed. Before conducting a visit, a detailed sampling plan showing the selected sample points was generated. Pertinent data to be obtained was detailed. For all sampling programs, flow proportioned composite samples, or the equivalent for batch operations, were taken while the plant was in operation.

The purpose of the sampling and analysis program was to determine both qualitative and quantitative data about the pollutants being introduced into the wastewaters of plants in the subcategory. Plants were selected for sampling when it was possible either to sample total raw wastewater or to make a flow proportioned composite equivalent of the total raw wastewater. The total raw wastewater represents the mixed process water from all processes has mixed prior to any treatment. Many wastewaters, however, receive some preliminary treatment before mixing (i.e., chromium wastewaters are generally treated to reduce hexavalent chromium before being mixed with other wastewaters). When this was the case the stream was also sampled prior to the individual stream treatment. Samples were taken for each operation which discharged or used process water, including any rinses following a treatment process.

The concentrations of parameters in the intake water to the plant are measured to see if pollutants are actually being introduced by the production operations or are present at background levels in the water being used. The analyses of these influent water samples revealed no significant quantities of pollutants. The final effluent was measured to determine the effectiveness of the wastewater treatment system. When streams were treated and discharged separately, all of the effluents were measured.

A blank sample was taken to see if any pollutants were being introduced into the other samples by the sampling equipment. A blank is made by drawing specially prepared organic-free water through the sampling equipment and handling it just as the other samples.

The samples were collected according to EPA protocol dated April 1977. The samples were collected through teflon and tygon tubing. The tygon tubing contains some of the priority pollutants; therefore, a tubing blank was collected. The methods used to analyze the samples collected are given in Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, U.S.EPA, March 1977, Revised April 1977.

Can manufacturing wastewater samples were analyzed for organics by gas chromatography-mass spectrophotomerty (GC-MS) techniques. The samples were analyzed for metals by either inductively coupled argon plasma emission spectrophotometry (ICAP) or atomic absorption spectrophotometry (AA) methods.

Pollutant 129, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), was not analyzed, because the hazards of transporting and storing reference samples are judged by EPA to be greater than the hazard posed by the lack of routine analysis of industrial wastewaters for this compound. Pollutants (17) bis(chloremethyl ether), (49) trichlorofluoromethane, and (50) dichlorodifluoromethane have been removed from the toxics list.

The analytical methods used did not separate the concentration of certain PAH pollutant parameter pairs - specifically pollutants (72) 1,2-benzanthracene, and (76) chrysene; (78) anthracene and (81) phenanthrene; and (74) 3,4-benzofluoranthene and (75) 11,12-benzofluoranthene.

Due to their very similar physical and chemical properties, it is extremely difficult to separate the seven polychlorinated biphenyls (pollutants 107-133 on the list of priority pollutants) for analytical identification and quantification. For that reason, the concentrations of the polychlorinated biphenyls are reported by the analytical laboratory in two groups: one group consists of (106) PCB-1242, (107) PCB-1254 and (108) PCB-1221; the other group consists of (109) PCB-1232, (110) PCB-1248, (111) PCB-1260 and (112) PCB-1016. For convenience, the first group will be referred to as PCB-1254 and the second as PCB-1248.

The results of the asbestos self-sampling of the effluent from one canmaking plant were negative when the standard analysis procedure was used.

A number of non-priority pollutants were also studied for the canmaking subcategory. These additional pollutants may be divided into two general groups:

Conventional	Nonconventional
oil and grease	alkalinity
total suspended solids (TSS)	aluminum
pH	calcium
	chemical oxygen demand (COD)
	fluoride
	iron
	magnesium
	manganese
	phenols (total)
	phosphorus
	sulfate
	total organic carbon
	total dissolved solids (TDS)

Two sources of information were used to identify possible pollutants in canmaking wastewaters; pollutants believed to be present by industry, and pollutants selected by the Agency after review of the processes and materials used by the industry. In the dcp survey, the 129 priority pollutants were listed and each facility was asked to indicate for each particular pollutant "Known To Be Present" (KTBP), "Believe To Be Present" (BTBP), "Believe To Be Absent" (BTBA), or "Known To Be Absent" (KTBA). KTBP and KTBA were to be indicated if the pollutant had been analyzed for and either detected or not detected. BTBP and BTBA were to be indicated if on the basis of knowledge of the process and materials toxic pollutants are believed to be introduced into the wastewater. For the toxic metals the results of the survey are shown in Table V-1 (page 40). Three pollutants (chromium, copper, and zinc) were often identified as present (KTBP or BTBP).

DATA ANALYSIS

Dcp and sampling data were used to obtain major pieces of information for further analysis including the production normalized water use (l/1000 cans) of the total canmaking process, flows for each process, the raw process wastewater pollutant levels from the total process, a statistical analysis of the raw process wastewater concentrations, and the pollutant levels, both concentration and mass, of the final effluents after wastewater treatment.

Water Use

Water is used in several key canmaking operations. It is the major component of the emulsified oils which provide cooling and lubrication during D&I operations, provides the mechanism for removing undesirable compounds from the basis material, and is the medium for the chemical reactions that occur on the basis material. Water is the medium that permits the high degree of automation associated with canmaking and the high quality of the finished product. The nature of canmaking operations, the number of cans processed, and the quantity and type of chemicals used produces a large volume of wastewater that requires treatment before discharge.

Dcp Data

Plants provided production information in the dcp including the number of canmaking lines, annual and average hourly production rates, and process wastewater discharge flow rates for the plant. This information was used to derive the production normalized water use flow for each plant which is equal to the process water flow divided by the number of cans produced multiplied by 1000 to obtain liters per 1000 cans. Table V-2 (page 41) summarizes dcp data for aluminum basis material can plants and Table V-3 (page 44) summarizes the information for steel basis material can plants. Plants which practice water reuse are noted on these tables.

Sampled Plant Data

Five plants were visited and sampled for this subcategory (see Table V-4, page 45). Daily water use flow measurements for each process were calculated and are shown in Table V-5 (page 46). Daily production information was also obtained and used to calculate the production normalized water use for each sampling day at each plant. This information is also summarized in Table V-5.

Water use data from both dcp and visit data were statistically analyzed to determine minimum, maximum, mean and median water use at all canmaking plants. Plants practicing water reuse following the surface treatment rinse in the canwasher were analyzed separately. Results of this analysis are shown in Table V-6 (page 47). As shown in the water use tables the variations in flow between aluminum and steel canmaking are not substantial enough to warrant making a separate subcategory.

Wastewater Characterization

Chemical analysis for pollutant parameters was performed on all the samples collected during the sampling program. At the five sampled plants (see Table V-4), samples of wastewater were taken from the canwasher at each discharge point. Samples were also taken at other canmaking process wastewater discharge points including oil sump discharges, ion exchange regeneration discharges, and fume scrubber discharges (see Table V-5). The canmaking processes are nearly the same in every facility. Small variations in chemical constituents and plant operation are claimed to give major advantages in product quality. Specific process detail and chemical formulations are not discussed because plants claimed that the small differences might reveal confidential information.

For each plant (except for the steel plant) total raw wastewater characteristics were either analyzed separately, where possible, or were flow proportioned and mathematically synthesized into one data point. Raw wastewater characteristics are displayed in Table V-7 (page 48) for each sampling day at each plant.

For the steel plant only the caustic wash sample is shown because this canwash stage is the major contributing source of pollutants for steel can manufacture. This sample was used to compare pollutants detected in steel with the aluminum data. As shown in Table V-7, all pollutants detected for steel were also detected in the aluminum wastewaters. Thus, the aluminum wastewaters alone can be used to represent raw waste for the subcategory.

The constituents in the raw wastewater include basis material, oils and components from the drawing lubricants, components of the acid treatment and conversion coating solutions, and the paints and solvents used in printing the cans. In Table V-7 pollutants that were not detected in all raw wastewater samples are not listed.

Chemical analysis of data include some data points of pollutants measured at levels considered not quantifiable. All organics except pesticides and cyanide are not considered quantifiable at concentrations equal to or less than 0.010 mg/l. Pesticides are not considered quantifiable at concentrations equal to or less than 0.005 mg/l. In Table V-7 these values are indicated by an "*" for equal to or less than 0.010 mg/l and "**" for pesticides.

The distinction of not quantifiable is made because the analyses used to measure the concentrations of these pollutants is not quantitatively accurate at these concentrations. The analyses are useful, however to indicate the detection of a particular pollutant. When two or more streams were proportioned to get the total raw waste, the total discharge concentration was considered not quantifiable only if the total concentration was calculated exclusively from not quantifiable values. A value of 0.001 mg/l for an organic is considered quantifiable if it results when a stream with a concentration of 0.020 mg/l is diluted 20 fold. For metals, the analytical methods used indicate either the detection of the metal at the amount shown or not detected at the analytical limits used.

A statistical analysis of the raw wastewater data is displayed in Table V-8 (page 50). Data points considered to be not quantifiable (* and **) were included in the analysis as 0.000 mg/l. This was done so as not to bias the statistical analyses.

The analysis by concentration is useful in understanding the functionality of the total canmaking process as well as each process step. High concentrations of particular constituents in a wastewater stream are indicators of the types of chemical reactions or mass transfer operations taking place. Concentrations do not indicate the amount of pollutants being introduced into wastewaters since a very large stream with low pollutant concentrations may contribute far more pollution than a very small stream with higher pollutant concentrations.

Only limited amounts of raw wastewater data were received in the dcp responses. The data were only for a few metals and were not useful for wastewater characterization.

Treatment In Place - Dcp and visit data (Table V-9, page 52) show current wastewater treatment systems in the subcategory range from no treatment to a sophisticated physical chemical treatment combined with water conservation practices.

No treatment equipment was reported in place at 8 canmaking plants. Oil removal equipment for skimming, chemical emulsion breaking or dissolved air flotation is in place at 53 canmaking plants, 7 plants have chromium reduction systems, 29 canmaking plants have pH adjustment systems without settling, 28 plants indicate they have equipment for chemical precipitation and settling, 10 plants have filtration equipment in place, 1 plant has ultrafiltration, and 1 plant has reverse osmosis equipment in place.

At four of the five sampled canmaking plants, reuse of oil from the oil sump was practiced.

Effluent Analysis - The performance of the treatment systems in place at all canmaking plants is difficult to assess because a limited amount of canmaking effluent data was received. The dcp effluent data are for a few metals only. The available data are summarized in Table V-10 (page 57).

Samples of the final effluents were taken for every day of sampling. Most effluents contained wastewaters or treated wastewaters from more than one canmaking line.

Table V-11 (page 58) shows the effluent concentrations from each plant that treated its wastewater for each sampling day. Total l/day for each data day are also shown. Table V-12 (page 60) displays the mass of pollutants discharged per 1000 cans produced. This production normalized effluent data was calculated by multiplying the concentrations for each pollutant in Table V-11 by the production normalized flow (l/1000 cans) for each sampling day shown in Table V-5 and also at the top of Table V-12.

TABLE V-1

DCP PRIORITY POLLUTANT RESPONSES

Priority Pollutant	Known To Be Present	Believed To Be Present	Believed To Be Absent	Known To Be Absent
114. Antimony	0	13	19	17
115. Arsenic	4	5	27	17
117. Beryllium	0	0	32	17
118. Cadmium	3	6	28	16
119. Chromium	38	8	8	1
120. Copper	8	34	10	3
121. Cyanide	4	0	28	17
122. Lead	17	12	21	4
123. Mercury	5	5	36	7
124. Nickel	16	13	18	6
125. Selenium	2	8	27	16
126. Silver	6	6	25	16
127. Thallium	0	3	30	16
128. Zinc	20	22	9	1

TABLE V-2

DCP DATA, ALUMINUM BASIS MATERIAL

Plant ID	No. of Lines	Average Production (Cans/Hr)	Process Wastewater (l/Hr)	Water Use ($l/10^3$ Cans)
401*	2	70,525	22,142	314.0
404*	6	198,900	47,010	236.3
410	2	NA	NA	NA
413	4	126,230	25,360	200.9
414	2	NA	NA	NA
423	2	87,200	24,712	283.4
432*	4	152,492	25,170	165.0
434	2	94,150	31,037	329.7
438	3	83,916	1,181	14.1
441*	3	79,800	18,509	231.9
453*	2	69,699	15,848	227.4
454*	4	144,000	26,609	184.8
457	2	NA	NA	NA
459*	2	81,972	5,450	66.5
471*	2	75,708	6,472	85.4
477*	4	68,552	15,897	231.9
481	3	NA	NA	NA
483*	2	68,887	27,233	395.0
485*	4	119,500	24,527	205.2
498	2	63,638	4,542	71.4
490*	4	70,812	22,710	320.7
492	2	NA	NA	NA

NA = Not Available
* = Water Reuse Practiced

TABLE V-2

DCP DATA, ALUMINUM BASIS MATERIAL (Continued)

Plant ID	No. of Lines	Average Production (Cans/Hr)	Process Wastewater (l/Hr)	Water Use ($l/10^3$ Cans)
499	2	NA	NA	NA
502*	3	97,800	13,891	142.0
508*	2	83,710	8,289	99.0
509*	3	41,980	10,440	248.7
511*	2	41,550	6,813	164.0
515*	2	81,888	6,548	80.0
523	4	106,465	39,743	373.3
524*	4	132,700	30,204	227.6
530*	2	69,502	11,355	163.4
539	2	NA	NA	NA
541	3	73,260	31,416	428.8
547	4	71,010	54,814	771.9
548	2	NA	NA	NA
550	4	603,573	7,949	13.2
555*	2	98,160	5,450	55.5
557	2	66,770	28,842	432.0
558	2	NA	NA	NA
565*	5	74,001	14,383	194.4
577*	5	186,000	18,849	101.3
578*	1	46,740	6,586	140.9
582	2	72,600	3,785	52.1
588*	3	81,850	18,395	224.7

NA = Not Available
 * = Water Reuse Practiced

TABLE V-2

DCP DATA, ALUMINUM BASIS MATERIAL (Continued)

Plant ID	No. of Lines	Average Production (Cans/Hr)	Process Wastewater (l/Hr)	Water Use ($l/10^3$ Cans)
604	2	77,000	34,936	453.7
605*	3	130,000	21,839	168
607*	4	149,000	34,519	231.7
608*	4	82,616	13,880	168.0
613	2	56,320	34,065	604.8
619	2	NA	NA	NA
622	2	NA	NA	NA
626	2	63,416	27,631	435.7
633	3	104,175	30,117	289.1
642	2	47,254	11,389	241.0
644	2	NA	NA	NA
648*	6	200,160	18,168	90.8
661*	3	86,464	12,634	146.1
666	3	101,000	26,495	262.3
667*	2	80,880	6,472	80.9
671	2	NA	NA	NA
673	2	NA	NA	NA
675	3	94,650	24,811	262.1
678*	2	68,256	5,450	79.9
688	3	113,103	6,813	60.2
689	2	NA	NA	NA
692*	2	93,000	17,127	184.2

NA = Not Available
* = Water Reuse Practiced

TABLE V-3

DCP DATA, STEEL BASIS MATERIAL

Plant ID	No. of Lines	Average Production (Cans/Hr)	Process Wastewater (l/Hr)	Water Use (l/10^3 Cans)
417	2	NA	NA	NA
424	4	112,026	7,570	67.6
440	1	23,598	2067	87.6
461	2	68,000	13,626	200.4
468	2	75,030	4,799	64.0
479	2	NA	NA	NA
489	3	20,000	NA	NA
497	2	58,560	7,752	132.4
525	1	30,000	5,829	194.3
531	2	NA	NA	NA
538	1	37,701	2,271	60.2
574	2	107,326	11,260	104.9
585	2	NA	NA	NA
587	1	27,000	7,040	260.7
592	2	NA	NA	NA
603	2	62,100	4,542	73.1
621	2	NA	NA	NA
631	2	NA	NA	NA
632	2	NA	NA	NA
641	1	36,300	1,893	52.1
655	4	55,000	8,630	156.9

NA - Not Available

TABLE V-4

LISTING OF SAMPLED CANMAKING PLANTS

	Plant ID	Days Sampled
Aluminum	488	3
	515	3
	557	3
	565	3
Steel	655	1

TABLE V-5
SAMPLED PLANT WATER USE

ALUMINUM BASIS MATERIAL

Plant ID (day)	Production (cans/day)	Drawing Wastewater (ℓ/day)	Prewash Wastewater (ℓ/day)	Cleaning Rinse Wastewater (ℓ/day)	Chemical Treatment Rinse Wastewater (ℓ/day)	DI Regenerate Wastewater (ℓ/day)	Wet Scrubber Wastewater (ℓ/day)	Total Wastewater (ℓ/day)	Total Water Use (ℓ/10^3 cans)
488 (1)	1,414,134	11,355	130,810		21,802		341	164,308	116.2
488 (2)	1,362,546	11,355	109,008		21,802		341	142,506	104.6
488 (3)	1,263,950	11,355	98,107		21,802		341	131,605	104.1
515 (1)	2,246,520		185,314			7,192		192,506	87.5
515 (2)	2,386,200		185,314					185,314	77.7
515 (3)	2,933,280		185,314					185,314	63.2
557 (1)	24,548,152							261,619	10.66
557 (2)	26,976,000							261,619	9.70
557 (3)	19,186,670							261,619	13.64
565 (1)	1,791,120		70,855	81,756	84,481			237,092	132.4
565 (2)	1,791,120		111,188	62,135	104,103			277,426	154.9
565 (3)	1,791,120		103,013	78,486	105,193			286,692	160.1
STEEL BASIS MATERIAL									
655 (1)	1,320,000							17,259	13.08

TABLE V-6

SUMMARY OF WATER USE ($\ell/10^3$ cans)

Functional Operation	Basis Material	Minimum	Maximum	Mean	Median	# Points
Visited Plants						
All Operations	Aluminum	9.7	160.1	86.1	94.9	12
DCP Responses						
All operations for plants re-using canwasher water	Aluminum	55.5	320.7	176.7	168	32
All operations	Aluminum Steel	52.1 52.1	771.9 260.7	232.0 121.2	215.0 96.3	48 12

TABLE V-7
SAMPLING ANALYSIS RESULTS
RAW WASTEWATER (mg/ℓ)

	ALUMINUM BASIS MATERIAL								
	488 (1)	488 (2)	488 (3)	515 (1)	515 (2)	515 (3)	557 (1)	557 (2)	557 (3)
4. Benzene	ND	ND	ND	*	*	*	ND	ND	ND
6. Carbon Tetrachloride	ND	ND	ND	*	ND	*	ND	ND	ND
7. Chlorobenzene	ND	ND	ND	ND	ND	ND	*	ND	ND
11. 1,1,1-Trichloroethane	*	0.015	0.118	*	*	0.034	0.980	2.8	1.100
18. Bis (2-chloroethyl) Ether	ND	ND	ND	ND	0.0103	*	ND	ND	ND
23. Chloroform	ND	ND	ND	*	*	*	ND	ND	ND
29. 1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND	0.050	0.170	0.060
37. 1,2-Diphenylhydrazine	ND	ND	ND	ND	ND	*	ND	ND	ND
38. Ethylbenzene	ND	ND	ND	*	*	*	ND	ND	ND
44. Methylene chloride	0.019	ND	ND	0.020	0.016	0.095	*	*	*
48. Dichlorobromomethane	ND	ND	ND	*	ND	ND	ND	ND	ND
51. Chlorodibromomethane	ND	ND	ND	*	*	ND	ND	ND	ND
55. Naphthalene	ND	ND	ND	ND	*	*	ND	ND	ND
62. N-Nitrosodiphenylamine	ND	ND	ND	ND	*	*	ND	ND	ND
65. Phenol	ND	ND	ND	ND	ND	*	ND	ND	ND
66. Bis (2-ethylhexyl) Phthalate	ND	ND	ND	4.100	2.700	0.540	0.08	0.330	ND
67. Butyl Benzyl Phthalate	ND	ND	ND	ND	ND	0.022	ND	ND	ND
68. Di-N-Butyl Phthalate	ND	ND	ND	0.775	0.680	0.400	*	ND	ND
70. Diethyl Phthalate	ND	ND	ND	ND	*	ND	ND	ND	ND
71. Dimethyl Phthalate	ND	ND	ND	ND	*	*	ND	ND	ND
72. 1,2-Benzanthracene	ND	ND	ND	ND	*	*	ND	ND	ND
76. Chrysene	ND	ND	ND	ND	*	*	ND	ND	ND
78. Anthracene	ND	ND	ND	*	*	*	ND	ND	ND
80. Fluorene	ND	ND	ND	ND	*	*	ND	ND	ND
81. Phenanthrene	ND	ND	ND	*	*	*	ND	ND	ND
85. Tetrachloroethylene	ND	ND	ND	*	*	*	ND	ND	ND
86. Toluene	ND	ND	ND	0.026	0.026	0.028	*	ND	*
87. Trichloroethylene	ND	ND	ND	*	*	*	ND	ND	ND
91. Chlordane	ND	ND	ND	**	NA	NA	ND	ND	ND
92. 4,4-DDT	ND	ND	ND	**	NA	NA	ND	ND	ND
93. 4,4-DDE	ND	ND	ND	**	NA	NA	ND	ND	ND
97. Endosulfan Sulfate	ND	ND	ND	**	NA	NA	ND	ND	ND
98. Endrin	ND	ND	ND	**	NA	NA	ND	ND	ND
100. Heptachlor	ND	ND	ND	**	NA	NA	ND	ND	ND
101. Heptachlor Epoxide	ND	ND	ND	**	NA	NA	ND	ND	ND
102. Alpha-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
103. Beta-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
104. Gamma-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
107. PCB-1254	ND	ND	ND	**	NA	NA	ND	ND	ND
110. PCB-1248	ND	ND	ND	**	NA	NA	ND	ND	ND
115. Arsenic	0.028	0.0275	1.402	ND	ND	ND	0.0037	0.0053	0.01145
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
118. Cadmium	0.010	0.0026	0.003	ND	ND	ND	0.0026	0.0029	0.00245
119. Chromium	0.134	0.1236	0.204	0.25	0.29	0.25	0.009	0.011	0.0195
120. Copper	0.051	0.053	0.064	0.07	0.07	0.09	0.021	0.014	0.015
121. Cyanide	0.004	0.0099	ND	0.004	0.005	0.003	ND	ND	ND
122. Lead	0.021	0.022	0.028	ND	ND	ND	0.014	0.039	0.032
123. Mercury	0.001	0.001	0.001	ND	0.0009	ND	0.0009	0.0004	0.0013
124. Nickel	0.020	0.0162	0.033	0.41	0.49	0.43	ND	ND	ND
128. Zinc	3.749	4.285	4.647	0.22	0.18	0.20	0.110	0.110	0.150
Aluminum	59.639	58.100	71.997	311	370	325	14.000	15.000	20.000
Calcium	59.107	58.044	57.504	NA	NA	NA	56.000	60.000	61.500
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron	1.165	1.119	1.605	5.4	5.4	5.4	0.320	0.130	0.335
Magnesium	15.221	15.299	15.05	NA	NA	NA	15.300	16.300	16.700
Manganese	0.399	0.573	0.768	4.4	5.2	4.3	0.330	0.340	0.345
Phenols	NA	NA	NA	0.014	0.020	0.019	0.016	0.010	ND
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	NA	NA	NA	600	820	690	NA	NA	NA
TDS	6373	8368	8519	3096	3440	2420	NA	NA	NA
Oil & Grease	4721	44054	45094	1461	727	901	229	305	329
TSS	3309	762	837	345	275	321	96	99	77
pH				1.9	1.8	1.8	6.2	6.1	6.2

* Possibly detected but ≤0.010 mg/l
** Possibly detected but ≤0.005 mg/l
ND Not detected
NA Not analyzed

TABLE V-7 (Continued)
SAMPLING ANALYSIS RESULTS
RAW WASTEWATER (mg/l)

	ALUMINUM BASIS MATERIAL						STEEL BASIS MATERIAL
	565 (1A)	565 (2A)	565 (3A)	565 (1B)	565 (2B)	565 (3B)	655 1/
4. Benzene	NA	NA	NA	NA	NA	NA	NA
6. Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA
7. Chlorobenzene	NA	NA	NA	NA	NA	NA	NA
11. 1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA
18. Bis (2-chloroethyl) Ether	NA	NA	NA	NA	NA	NA	NA
23. Chloroform	NA	NA	NA	NA	NA	NA	NA
29. 1,1-Dichloroethylene	NA	NA	NA	NA	NA	NA	NA
37. 1,2-Diphenylhydrazine	NA	NA	NA	NA	NA	NA	NA
38. Ethylbenzene	NA	NA	NA	NA	NA	NA	NA
44. Methylene chloride	NA	NA	NA	NA	NA	NA	NA
48. Dichlorobromomethane	NA	NA	NA	NA	NA	NA	NA
51. Chlorodibromomethane	NA	NA	NA	NA	NA	NA	NA
55. Naphthalene	NA	NA	NA	NA	NA	NA	NA
62. N-Nitrosodiphenylamine	NA	NA	NA	NA	NA	NA	NA
65. Phenol	NA	NA	NA	NA	NA	NA	NA
66. Bis (2-ethylhexyl) Phthalate	NA	NA	NA	NA	NA	NA	NA
67. Butyl Benzyl Phthalate	NA	NA	NA	NA	NA	NA	NA
68. Di-N-Butyl Phthalate	NA	NA	NA	NA	NA	NA	NA
70. Diethyl Phthalate	NA	NA	NA	NA	NA	NA	NA
71. Dimethyl Phthalate	NA	NA	NA	NA	NA	NA	NA
72. 1,2-Benzanthracene	NA	NA	NA	NA	NA	NA	NA
76. Chrysene	NA	NA	NA	NA	NA	NA	NA
78. Anthracene	NA	NA	NA	NA	NA	NA	NA
80. Fluorene	NA	NA	NA	NA	NA	NA	NA
81. Phenanthrene	NA	NA	NA	NA	NA	NA	NA
85. Tetrachloroethylene	NA	NA	NA	NA	NA	NA	NA
86. Toluene	NA	NA	NA	NA	NA	NA	NA
87. Trichloroethylene	NA	NA	NA	NA	NA	NA	NA
91. Chlordane	NA	NA	NA	NA	NA	NA	NA
92. 4,4-DDT	NA	NA	NA	NA	NA	NA	NA
92. 4,4-DDE	NA	NA	NA	NA	NA	NA	NA
97. Endosulfan Sulfate	NA	NA	NA	NA	NA	NA	NA
98. Endrin	NA	NA	NA	NA	NA	NA	NA
100. Heptachlor	NA	NA	NA	NA	NA	NA	NA
101. Heptachlor Epoxide	NA	NA	NA	NA	NA	NA	NA
102. Alpha-BHC	NA	NA	NA	NA	NA	NA	NA
103. Beta-BHC	NA	NA	NA	NA	NA	NA	NA
104. Gamma-BHC	NA	NA	NA	NA	NA	NA	NA
107. PCB-1254	NA	NA	NA	NA	NA	NA	NA
110. PCB-1248	NA	NA	NA	NA	NA	NA	NA
115. Arsenic	ND	ND	ND	ND	ND	ND	ND
117. Beryllium	NA	NA	NA	NA	NA	NA	ND
118. Cadmium	ND	ND	ND	ND	ND	ND	ND
119. Chromium	2.106	1.878	5.410	0.777	1.160	2.468	0.020
120. Copper	0.017	0.019	0.028	0.015	0.019	0.020	ND
121. Cyanide	0.031	0.026	0.031	0.034	0.028	0.034	NA
122. Lead	ND	ND	0.052	ND	ND	ND	0.005
123. Mercury	ND	ND	ND	ND	ND	ND	NA
124. Nickel	ND	0.008	ND	ND	0.010	ND	0.040
128. Zinc	0.037	0.033	0.037	0.041	0.036	0.029	ND
Aluminum	NA	NA	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	NA	NA
Fluoride	15.66	15.36	16.75	16.99	17.65	18.02	0.880
Iron	0.146	0.142	0.159	0.131	0.142	0.162	0.700
Magnesium	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	0.012
Phenols	0.013	0.010	0.009	0.013	0.007	0.009	NA
Phosphorus	5.88	5.067	12.90	3.216	3.091	6.23	16.50
Sulfate	NA	NA	NA	NA	NA	NA	NA
TDS	NA	NA	NA	NA	NA	NA	NA
Oil & Grease	196.6	139.1	226.2	193.3	134.6	222.2	140.0
TSS	182.9	121.18	178.4	181.5	111.5	167.9	96.5
pH							8.6

1/ Sample analysis from caustic wash stage
* Possibly detected but ≤0.010 mg/l
** Possibly detected but ≤0.005 mg/l
ND Not detected
NA Not analysed

TABLE V-8

STATISTICAL ANALYSIS
RAW WASTEWATER POLLUTANTS (mg/ℓ)
ALUMINUM BASIS MATERIAL

	Parameter	Minimum	Maximum	Mean	Median	# Quantifiable Points	# Not Detected Points	# Nonquantifiable Points
4.	Benzene	*	*	*	*	0	6	3
6.	Carbon Tetrachloride	*	*	*	*	0	7	2
7.	Chlorobenzene	*	*	*	*	0	8	1
11.	1,1,1-Trichloroethane	*	2.8	0.561	0.034	6	0	3
18.	Bis (2-chloroethyl) Ether	*	0.0103	*	*	1	6	1
23.	Chloroform	*	*	*	*	0	6	3
29.	1,1-Dichloroethylene	0.050	0.170	0.093	0.060	3	6	0
37.	1,2-Diphenylhydrazine	*	*	*	*	0	8	1
38.	Ethylbenzene	*	*	*	*	0	6	3
44.	Methylene Chloride	*	0.095	0.022	0.016	4	2	3
48.	Dichlorobromomethane	*	*	*	*	0	8	1
51.	Chlorodibromomethane	*	*	*	*	0	7	2
55.	Naphthalene	*	*	*	*	0	7	2
62.	N-Nitrosodiphenylamine	*	*	*	*	0	7	2
65.	Phenol	*	*	*	*	0	8	1
66.	Bis (2-ethylhexyl) Phthalate	0.08	4.100	1.55	0.540	5	4	0
67.	Butyl Benzyl Phthalate	0.022	0.022	0.022	0.022	1	8	0
68.	Di-N-Butyl Phthalate	*	0.775	0.464	0.540	3	5	1
70.	Diethyl Phthalate	*	*	*	*	0	8	1
71.	Dimethyl Phthalate	*	*	*	*	0	7	2
72.	1,2-Benzanthracene	*	*	*	*	0	7	2
76.	Chrysene	*	*	*	*	0	7	2
78.	Anthracene	*	*	*	*	0	6	3
80.	Fluorene	*	*	*	*	0	7	2
81.	Phenanthrene	*	*	*	*	0	6	3

* Not quantifiable ≤0.010 mg/ℓ
** Not quantifiable ≤0.005 mg/ℓ

TABLE V-8 (Continued)

STATISTICAL ANALYSIS
RAW WASTEWATER POLLUTANTS (mg/ℓ)
ALUMINUM BASIS MATERIAL

	Parameter	Minimum	Maximum	Mean	Median	# Quantifiable Points	# Not Detected Points	# Nonquantifiable Points
85.	Tetrachloroethylene	*	*	*	*	0	6	3
86.	Toluene	*	0.028	0.016	0.026	3	4	2
87.	Trichloroethylene	*	*	*	*	0	6	3
91.	Chlordane	**	**	**	**	0	6	1
92.	4,4-DDT	**	**	**	**	0	6	1
93.	4,4-DDE	**	**	**	**	0	6	1
97.	Endosulfan sulfate	**	**	**	**	0	6	1
98.	Endrin	**	**	**	**	0	6	1
100.	Heptachlor	**	**	**	**	0	6	1
101.	Heptachlor Epoxide	**	**	**	**	0	6	1
102.	Alpha-BHC	**	**	**	**	0	6	1
103.	Beta-BHC	**	**	**	**	0	6	1
104.	Gamma-BHC	**	**	**	**	0	6	1
107.	PCB-1254	**	**	**	**	0	6	1
110.	PCB-1248	**	**	**	**	0	6	1
115.	Arsenic	0.0037	1.402	0.246	0.019	6	9	
118.	Cadmium	0.0026	0.010	0.004	0.003	6	9	
119.	Chromium, Total	0.009	5.41	1.006	0.25	15	0	
120.	Copper	0.014	0.09	0.038	0.021	15	0	
121.	Cyanide	0.003	0.034	0.019	0.026	11	4	
122.	Lead	0.014	0.052	0.030	0.028	7	8	
123.	Mercury	0.0004	0.0013	0.0009	0.001	7	8	
124.	Nickel	0.008	0.49	0.177	0.027	8	7	
128	Zinc	0.029	4.647	0.924	0.110	15	0	
	Aluminum	14.000	370	138.3	59.639	9	0	
	Fluoride	15.36	18.02	16.74	16.87	6	0	
	Iron	0.13	5.4	1.397	0.32	15	0	
	Manganese	0.33	5.2	1.851	0.573	9	0	
	Phenols	0.007	0.02	0.013	0.013	11	1	
	Phosphorus	3.091	12.9	6.06	5.47	6	0	
	Oil & Grease	134.6	45094	6596	305	15	0	
	TSS	77	3309	471	181.5	15	0	

TABLE V-9

TREATMENT IN PLACE AT CANMAKING PLANTS

ALUMINUM BASIS MATERIAL

PLANT	Discharge Status	Equalization	Chemical Emulsion Breaking	Dissolved Air Flotation	Gravity Oil Separation	Chromium Reduction	Neutralization	Settling	Clarification	Filtration	Sludge Dewatering	Cooling Tower	No Treatment
401	I	X	X	X	X			X			X		
404	I	X	X	X	X		X			X			
410	I				X								
413	I						X						
414	D				X								
423	I												X
432	I	X			X		X						
434	I						X					X	
438	I	X					X			X			
441	I	X			X		X						
453	I						X						
454	I	X			X		X	X	X			X	
457	I				X								
459	I	X					X		X				
471	I	X					X		X				
477	I			X	X		X	X					

I = Indirect
D = Direct

TABLE V-9 (Continued)

TREATMENT IN PLACE AT CANMAKING PLANTS

ALUMINUM BASIS MATERIAL

PLANT	Discharge Status	Equalization	Chemical Emulsion Breaking	Dissolved Air Flotation	Gravity Oil Separation	Chromium Reduction	Neutralization	Settling	Clarification	Filtration	Sludge Dewatering	Cooling Tower	No Treatment
483	I				X		X						
485	I	X			X	X	X						
488	I	X	X	X	X		X		X	X	X		
490	I				X		X						
492	I				X								
499	I				X								
502	I				X		X						
508	I						X	X	X		X	X	
509	I	X					X	X		X		X	
511	I	X	X	X	X		X		X		X	X	
515*	I	X			X		X		X	X			
523	I						X					X	
524	I	X	X	X	X		X						
530	D	X			X	X	X	X	X		X	X	
541	I						X					X	
547	I		X		X	X						X	

* At time of sampling visit, an oil separator had been installed.

TABLE V-9 (Continued)

TREATMENT IN PLACE AT CANMAKING PLANTS

ALUMINUM BASIS MATERIAL

PLANT	Discharge Status	Equalization	Chemical Emulsion Breaking	Dissolved Air Flotation	Gravity Oil Separation	Chromium Reduction	Neutralization	Settling	Clarification	Filtration	Sludge Dewatering	Cooling Tower	NO Treatment
548	I				X								
550	I		X	X	X		X						
555	I	X			X		X		X				
557*	I	X			X		X						
558	I				X								
565**	I	X			X	X	X		X				
577	D	X			X		X		X		X		
578	I	X					X		X				
582	I		X	X	X		X				X		
588	I	X	X	X	X		X						
604	I						X					X	
605	D				X		X	X	X		X	X	
607	I	X	X		X		X						
608	I						X						
613	I						X					X	
619	D			X	X								
622	I				X								
626	I												X

* At time of sampling visit pH adjustment (neutralization) was eliminated.

** Fluoride treatment also reported; at time of sampling visit oil separator had been installed.

TABLE V-9 (Continued)

TREATMENT IN PLACE AT CANMAKING PLANTS

ALUMINUM BASIS MATERIAL

PLANT	Discharge Status	Equalization	Chemical Emulsion Breaking	Dissolved Air Flotation	Gravity Oil Separation	Chromium Reduction	Neutralization	Settling	Clarification	Filtration	Sludge Dewatering	Cooling Tower	NO Treatment
633	I	X		X	X		X		X				
642	I	X	X	X	X		X	X	X		X		
644	I				X								
648	I	X					X						
661	I		X		X	X	X	X		X	X		
666	D				X		X	X	X	X	X	X	
667	I	X			X		X		X		X		
673	I				X		X					X	
675	D		X		X		X		X				
678	I	X					X		X				
688	I		X	X	X		X		X	X		X	
689	I				X								
692	I	X					X						

TABLE V-9 (Continued)

TREATMENT IN PLACE AT CANMAKING PLANTS

STEEL BASIS MATERIAL

PLANT	Discharge Status	Equalization	Chemical Emulsion Breaking	Dissolved Air Flotation	Gravity Oil Separation	Chromium Reduction	Neutralization	Settling	Clarification	Filtration	Sludge Dewatering	Cooling Tower	No Treatment
417	I												X
424	I				X								
440	I												X
461	I						X					X	
468	I	X			X		X	X	X				
479	I												X
489	I												X
497	I		X		X								
525	I					X	X	X	X		X		
531	I				X								
538	I		X	X	X		X		X	X	X	X	
574	I			X	X		X		X		X	X	
585	I						X						
587	I					X	X	X	X		X		
592	I				X								
603	I												X
621	I	X			X		X			X			
641	I		X	X	X		X				X		
655	I												X

TABLE V-10

DCP EFFLUENT DATA (mg/ℓ)

Plant ID	Cr	Zn	Al	F	Fe	Mn	P	O&G	TSS	pH	
					POLLUTANT						
423	0.10		15					100	1000	6.5	
432	<0.05								196	8.6	
453	2.24			32				168			
454								70	100	8.0	
468	<0.04	0.17	<0.44		0.72	<0.10		12.3	926.4	8.0	
471						1.53		16		6.25	
477	0.03	<0.05				0.6		175		8.0	
488									189		
497		0.19*			0.396*				32.8*	7.9*	*Average of 11 samples
502	0.09				0.7			3550	1840	6.55	
508	0.28	0.4						38	80	7.2	
509			65.9		1.4			480	1570	8.6*	*Average of 2 samples
511	0.07										
525							1.99		25	8.4	
530				10-26				46-103			
531	0.045*				0.052*			32.1*	62.5*	8.1*	*Average of 4 samples
547	1.7		68					99	124	5.6	
565	0.048*	0.023**						52.7	10.7*	6.88*	*Average of 6 samples
574									100		
577			0.51	1.2						7.1	
578	<0.05	0.02						17	6		
587	0.14										
605			2.88						9	7.7	
607	0.15	0.4							259		
608	1.37		33.12	18.08	0.05		4.31	41	172		
626								107	120		
667								66	14		
688								100			

* = Mean values were calculated where more than one data point was available.
** = Value is an average of 3 data points.

TABLE V-11
SAMPLED PLANTS EFFLUENT DATA (mg/ℓ)
ALUMINUM BASIS MATERIAL 1/

Plant ID (Day) Flow (ℓ/day)	488 (1) 164,308	488 (2) 142,506	488 (3) 131,605	515 (1) 185,314	515 (2) 185,314	515 (3) 185,314	557 (1) 261,619	557 (2) 261,619	557 (3) 261,619	565 (1) 237,092	565 (2) 277,426	565 (3) 286,692
Pollutant												
4. Benzene	ND	ND	ND	*	ND	*	ND	ND	ND	NA	NA	NA
11. 1,1,1-Trichloroethane	0.020	*	*	0.061	0.022	0.031	0.770	1.50	*	NA	NA	NA
13. 1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	*	ND	NA	NA	NA
22. Parachlorometa cresol	ND	ND	ND	ND	0.038	ND	ND	ND	ND	NA	NA	NA
23. Chloroform	ND	ND	ND	*	0.012	0.015	ND	ND	ND	NA	NA	NA
30. 1,2-Trans-Dichloroethylene	ND	ND	ND	ND	ND	ND	0.040	ND	ND	NA	NA	NA
38. Ethylbenzene	ND	ND	ND	*	0.017	0.014	ND	ND	ND	NA	NA	NA
44. Methylene chloride	0.020	*	*	0.150	0.074	0.203	*	ND	*	NA	NA	NA
48. Dichlorobromomethane	ND	ND	ND	ND	ND	*	ND	ND	ND	NA	NA	NA
51. Chlorodibromothethane	ND	ND	ND	*	ND	ND	ND	ND	ND	NA	NA	NA
55. Naphthalene	ND	ND	ND	ND	0.037	0.057	ND	ND	ND	NA	NA	NA
65. Phenol	ND	0.050	0.060	*	*	*	ND	ND	ND	NA	NA	NA
66. Bis(2-ethylhexyl)phthalate	ND	0.050	0.480	0.500	0.850	0.461	0.040	0.020	ND	NA	NA	NA
68. Di-n-butyl phthalate	ND	ND	ND	0.300	0.505	ND	ND	ND	ND	NA	NA	NA
85. Tetrachloroethylene	ND	ND	ND	*	ND	ND	ND	ND	ND	NA	NA	NA
86. Toluene	*	*	ND	0.023	0.018	0.036	*	*	*	NA	NA	NA
87. Trichloroethylene	ND	ND	ND	*	ND	*	ND	ND	ND	NA	NA	NA
92. 4,4'-DDT	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
93. 4,4-DDE	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
98. Endrin	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
100. Heptachlor	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
102. Alpha-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
103. Beta-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
104. Gamma-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
105. Delta-BHC	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
106. PCB-1242	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
107. PCB-1254	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
108. PCB-1221	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
109. PCB-1332	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
110. PCB-1248	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA

*	Possibly detected but ≤0.010 mg/1.
**	Possibly detected but ≤0.005 mg/1.
NA	Not analyzed.
ND	Not detected.
1/	Effluent Data for Steel Basis Material (Plant 655) is the same as raw waste.

TABLE V-11 (Continued)
SAMPLED PLANTS EFFLUENT DATA (mg/ℓ)
ALUMINUM BASIS MATERIAL

Plant ID (Day)	488 (1)	488 (2)	488 (3)	515 (1)	515 (2)	515 (3)	557 (1)	557 (2)	557 (3)	565 (1)	565 (2)	565 (3)
Pollutant												
111. PCB-1260	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
115. Arsenic	0.210	0.081	0.160	ND	ND	ND	0.0041	0.0045	0.011	ND	ND	ND
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
118. Cadmium	0.0093	0.013	ND	ND	ND	ND	0.0026	0.003	0.0035	ND	ND	ND
119. Chromium	0.170	0.130	0.220	ND	ND	ND	0.021	0.013	0.019	0.15	0.12	0.039
120. Copper	0.070	ND	0.083	ND	0.02	0.02	0.070	0.024	0.022	ND	ND	0.016
121. Cyanide	NA	0.02	ND	0.110	0.049	0.027	ND	ND	ND	ND	0.018	ND
122. Lead	ND	0.054	0.004	ND	ND	ND	0.028	0.018	0.036	ND	ND	ND
123. Mercury	0.0022	0.0042	ND	ND	ND	ND	0.0008	0.0004	0.0009	ND	ND	ND
124. Nickel	0.026	0.021	0.130	0.19	0.05	0.02	0.003	ND	ND	ND	ND	ND
128. Zinc	3.2	1.60	5.90	0.08	0.05	0.05	0.180	0.110	0.140	0.015	0.028	0.013
Aluminum	770	250	570	79	4.6	NA	14	15	18	NA	NA	NA
Calcium	56	61.0	66	NA	NA	NA	62.0	62.0	60.0	NA	NA	NA
COD	8,550	1,880	6,640	1380	1860	2080	500	317	739	NA	NA	NA
Fluoride	NA	53	61	NA	NA	NA	NA	NA	NA	23.0	27.0	22.0
Iron	1.3	2.0	1.7	0.28	0.49	0.45	0.140	0.290	0.300	0.087	0.067	0.067
Magnesium	11.9	13.5	15.0	NA	NA	NA	16.3	15.9	16.2	NA	NA	NA
Manganese	NA	0.49	0.750	3.8	1.6	1.4	0.310	0.330	0.340	NA	NA	NA
Phenols	0.103	NA	0.014	0.010	0.008	0.010	0.059	0.014	0.007	0.010	0.019	0.005
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.46	0.40	0.41
Sulfate	2,800	1,500	2,980	570	570	NA	NA	NA	NA	NA	NA	NA
TOC	435	180	1,165	NA	NA	NA	87	91	76	NA	NA	NA
Oil & Grease	780	3,930	490	NA	NA	NA	222	385	326	25	12	16
TSS	55,000	1,210	4,720	60	56	159	108	104	125	13	14	23
pH	8.4	8.4	8.7	5.9	6.9	7.3	6.1	6.4	NA	7.9	7.7	8.4
Temperature, C	24	31	31	28.5	28	29	26	29	NA	28	28	29

TABLE V-12
SAMPLED PLANTS EFFLUENT DATA (mg/10^3 cans)
ALUMINUM BASIS MATERIAL

Plant ID (Day)	488 (1)	488 (2)	488 (3)	515 (1)	515 (2)	515 (3)	557 (1)	557 (2)	557 (3)	565 (1)	565 (2)	565 (3)
Flow (ℓ/10^3 cans)	116.2	104.6	104.1	85.7	77.7	63.2	10.66	9.70	13.64	132.4	154.9	160.1
Pollutant												
4. Benzene	ND	ND	ND	0.0	ND	0.0	ND	ND	ND	NA	NA	NA
11. 1,1,1-Trichloroethane	2.324	0.0	0.0	5.23	1.709	1.959	8.21	14.55	0.0	NA	NA	NA
13. 1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	0.0	ND	NA	NA	NA
22. Parachlorometa cresol	ND	ND	ND	ND	0.0	ND	ND	ND	ND	NA	NA	NA
23. Chloroform	ND	ND	ND	0.0	0.932	0.948	ND	ND	ND	NA	NA	NA
30. 1,2-Trans-Dichloroethylene	ND	ND	ND	ND	ND	ND	0.426	ND	ND	NA	NA	NA
38. Ethylbenzene	ND	ND	ND	0.0	1.321	0.885	ND	ND	ND	NA	NA	NA
44. Methylene chloride	2.324	0.0	0.0	12.86	5.75	12.83	0.0	ND	0.0	NA	NA	NA
48. Dichlorobromomethane	ND	ND	ND	ND	ND	0.0	ND	ND	ND	NA	NA	NA
51. Chlorodibromothethane	ND	ND	ND	0.0	ND	ND	ND	ND	ND	NA	NA	NA
55. Naphthalene	ND	ND	ND	ND	2.875	3.602	ND	ND	ND	NA	NA	NA
65. Phenol	ND	5.23	6.25	0.0	0.0	0.0	ND	ND	ND	NA	NA	NA
66. Bis(2-ethylhexyl)phthalate	ND	5.23	49.97	42.85	66.0	29.13	0.426	0.194	ND	NA	NA	NA
68. Di-n-butyl phthalate	ND	ND	ND	25.1	39.24	ND	ND	ND	ND	NA	NA	NA
85. Tetrachloroethylene	ND	ND	ND	0.0	ND	ND	ND	ND	ND	NA	NA	NA
86. Toluene	0.0	0.0	ND	1.971	1.399	2.275	0.0	0.0	0.0	NA	NA	NA
87. Trichloroethylene	ND	ND	ND	0.0	ND	0.0	ND	ND	ND	NA	NA	NA
92. 4,4'-DDT	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
93. 4,4-DDE	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
98. Endrin	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
100. Heptachlor	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
102. Alpha-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
103. Beta-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
104. Gamma-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
105. Delta-BHC	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
106. PCB-1242	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
107. PCB-1254	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
108. PCB-1221	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA

TABLE V-12 (Continued)
SAMPLED PLANTS EFFLUENT DATA (mg/10^3 cans)
ALUMINUM BASIS MATERIAL

Plant ID (Day)	488 (1)	488 (2)	488 (3)	515 (1)	515 (2)	515 (3)	557 (1)	557 (2)	557 (3)	565 (1)	565 (2)	565 (3)
Pollutant												
109. PCB-1332	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
110. PCB-1248	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
111. PCB-1260	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
115. Arsenic	24.40	8.473	16.65	ND	ND	ND	0.0437	0.0436	0.15	ND	ND	ND
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
118. Cadmium	1.081	1.36	0.0937	ND	ND	ND	0.0277	0.0291	0.0477	ND	ND	ND
119. Chromium	19.75	13.6	22.9	ND	ND	ND	0.224	0.126	0.259	19.86	18.59	6.244
120. Copper	8.134	ND	8.64	ND	1.554	1.264	0.746	0.233	0.30	ND	ND	2.562
121. Cyanide	ND	2.092	ND	9.427	3.807	1.706	ND	ND	ND	ND	2.79	ND
122. Lead	0.116	5.648	0.416	ND	ND	ND	0.298	0.175	0.491	ND	ND	ND
123. Mercury	ND	0.439	ND	ND	ND	ND	0.00853	0.00388	0.0123	ND	ND	ND
124. Nickel	3.021	2.196	13.53	16.28	3.885	1.264	0.032	ND	ND	ND	ND	ND
128. Zinc	371.8	167.4	614.19	6.856	3.885	3.16	1.919	1.067	1.91	1.986	4.34	2.08
Aluminum	89,474	26,150	59,337	6,770	357.4	NA	149.2	145.5	245.5	NA	NA	NA
Calcium	6,507	6,381	6,870	NA	NA	NA	661	601	818	NA	NA	NA
COD	993,510	196,648	691,224	118,266	144,522	131,456	5,330	3,074	10,080	NA	NA	NA
Fluoride	NA	5,543	6,350	NA	NA	NA	174	154	221	3,045	4,182	3,522
Iron	151.1	209.2	176.97	23,996	38.07	28.44	1.492	2.813	4.09	11.52	10.38	10.73
Magnesium	1,382	1,412	1,561	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	ND	51.25	78.08	325.7	124.3	88.48	3.305	3.20	4.64	NA	NA	NA
Phenols	11.97	NA	1.457	0.857	0.622	0.632	0.629	0.136	0.0955	1.324	2.943	ND
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	NA	193.3	61.96	65.64
Sulfate	325,360	156,900	310,218	48.85	44,289	NA	NA	NA	NA	NA	NA	NA
TOC	50,547	18,828	121,276	NA	NA	NA	927.4	882.7	1,036	NA	NA	NA
Oil & Grease	90,636	411,078	51,009	NA	NA	NA	2,366	3,734	4,446	3,310	1,858	2,561
TSS	6,391,000	126,566	491,352	5,142	4,351	10,048	1,151	1,008	1,705	1,721	2,168	3,682
pH	8.4	8.6	8.7	5.9	6.9	7.3	6.1	6.4	NA	8.3	7.7	8.4
Temperature, C	24	31	31	28.5	28	29	26	29	NA	28	28	29

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Section V presented pollutant parameters to be examined for possible regulation along with data from plant sampling visits and subsequent chemical analysis. Priority, non-conventional, and conventional pollutant parameters were selected according to a specified rationale. Pollutant parameters not detected, or detected at not quantifiable concentrations were eliminated from further consideration for regulation. All others which were detected are discussed in this section. The selected priority pollutant parameters are discussed in numerical order, followed by non-conventional pollutants and then conventional pollutant parameters, each in alphabetical order.

Finally, the pollutant parameters selected for consideration for specific regulation and those dropped from further consideration are set forth. The rationale for that selection is also presented. The occurence and levels of pollutants found are drawn from Table V-8 (page 50).

POLLUTANT PARAMETERS

Table VI-1 (page 98) lists all the priority pollutant parameters. For those not followed by an ND or NQ a discussion is presented in this section. The discussion provides information about: where the pollutant comes from - whether it is a naturally occurring element, processed metal, or manufactured compound; general physical properties and the form of the pollutants; toxic effects of the pollutant in humans and other animals; and behavior of the pollutant in POTW at the concentrations that might be expected from industrial discharges. Specific literature relied upon for the following discussion is listed in Section XV. Particular weight has been given to documents generated by the EPA Criteria and Standards Division and Monitoring and Data Support Division.

1,1,1-Trichloroethane(11). 1,1,1-Trichloroethane is one of the two possible trichloroethanes. It is manufactured by hydrochlorinating vinyl chloride to 1,1-dichloroethane which is then chlorinated to the desired product. 1,1,1-Trichloroethane is a liquid at room temperature with a vapor pressure of 96 mm Hg at 20°C and a boiling point of 74°C. Its formula is CCl_3CH_3. It is slightly soluble in water (0.48 g/l) and is very soluble in organic solvents. U.S. annual production is greater than one-third of a million tons.

1,1,1-Trichloroethane is used as an industrial solvent and degreasing agent.

Most human toxicity data for 1,1,1-trichloroethane relates to inhalation and dermal exposure routes. Limited data are available for determining toxicity of ingested 1,1,1-trichloroethane, and those data are all for the compound itself not solutions in water. No data are available regarding its toxicity to fish and aquatic organisms. For the protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through the consumption of water and fish, the ambient water criterion is 18.4 mg/l. The criterion is based on bioassay for possible carcinogenicity.

No detailed study of 1,1,1-trichloroethane behavior in POTW is available; however, it has been demonstrated that none of the organic priority pollutants of this type can be broken down by biological treatment processes as readily as fatty acids, carbohydrates, or proteins.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory scale studies at concentrations higher than commonly expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a moderate degree of degradation of 1,1,1-trichloroethane. No evidence is available for drawing conclusions about its possible toxic or inhibitory effect on POTW operation; however, for degradation to occur, a fairly constant input of the compound would be necessary.

Its water solubility would allow 1,1,1-trichloroethane, present in the influent and not biodegradable, to pass through a POTW into the effluent. One factor which has received some attention, but no detailed study, is the volatilization of the lower molecular weight organics from POTW. If 1,1,1-trichloroethane is not biodegraded, it will volatilize during aeration processes in the POTW.

1,1-Dichloroethylene(29). 1,1-Dichloroethylene (1,1-DCE), also called vinylidene chloride, is a clear colorless liquid manufactured by dehydrochlorination of 1,1,2-trichloroethane. 1,1-DCE has the formula CCl_2CH_2. It has a boiling paint of 32°C, and a vapor pressure of 591 mm Hg at 25°C. 1,1-DCE is slightly soluble in water (2.5 mg/l) and is soluble in many organic solvents. U.S. production is in the range of hundreds of thousands of tons annually.

1,1-DCE is used as a chemical intermediate and for copolymer coatings or films. It may enter the wastewater of an industrial facility as the result of decomposition of 1,1,1-trichloroethylene used in degreasing operations, or by migration from vinylidene chloride copolymers exposed to the process water.

Human toxicity of 1,1-DCE has not been demonstrated, although it is a suspected human carcinogen. Mammalian toxicity studies have focused on the liver and kidney damage produced by 1,1-DCE. Various changes occur in those organs in rats and mice ingesting 1,1-DCE.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 1,1-dichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. The concentration of 1,1-DCE estimated to result in an additional lifetime cancer risks of 10^{-4}, 10^{-5}, and 10^{-6} are 3.3 x 10^{-6} mg/l, 3.3 x 10^{-7} mg/l, and 3.3 x 10^{-4} mg/l. If contaminated organisms alone are consumed excluding the consumption of water, the water concentration should be less than 0.019 mg/l to keep the lifetime cancer risk below 10^{-5}.

Under laboratory conditions, dichloroethylenes have been shown to be toxic to fish. Limited acute and chronic toxicity data for aquatic life show that adverse effects occur at concentrations higher than those cited for human health risks. The primary effect of acute toxicity of the dichloroethylenes is depression of the central nervous system. The octanol-water partition coefficident of 1,1-DCE indicates it should not accumulate significantly in animals.

The behavior of 1,1-DCE in POTW has not been studied. However, its very high vapor pressure is expected to result in release of significant percentages of this material to the atmosphere in any treatment involving aeration. Degradation of dichloroethylene in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment in POTW produces little or no biochemical oxidation of 1,1-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,1-DCE on POTW operation. Because of water solubility, 1,1-DCE which is not volatilized or degraded is expected to pass through POTW. Very little 1,1-DCE is expected to be found in sludge from POTW.

Methylene Chloride (44). Methylene chloride, also called dichlormethane (CH_2Cl_2), is a colorless liquid manufactured by chlorination of methane or methyl chloride followed by separation from the higher chlorinated methanes formed as coproducts. Methylene chloride boils at 40°C, and has a vapor pressure of 362 mm Hg at 20°C. It is slightly soluble in water (20 g/l at 20°C), and very soluble in organic solvents. U.S. annual production is about 250,000 tons.

Methylene chloride is a common industrial solvent found in insecticides, metal cleaners, paint, and paint and varnish removers.

Methylene chloride is not generally regarded as highly toxic to humans. Most human toxicity data are for exposure by inhalation. Inhaled methylene chloride acts as a central nervous system depressant. There is also evidence that the compound causes heart failure when large amounts are inhaled.

Methylene chloride does produce mutation in tests for this effect. In addition, a bioassay recognized for its extremely high sensitivity to strong and weak carcinogens produced results which were marginally significant. Thus potential carcinogenic effects of methylene chloride are not confirmed or denied, but are under continuous study. Difficulty in conducting and interpreting the test results from the low boiling point (40°C) of methylene chloride which increases the difficulty of maintaining the compound in growth media during incubation at 37°C; and from the difficulty of removing all impuities, some of which might themselves be carcinogenic.

For the protection of human health from the toxic properties of methylene chloride ingested through water and contaminated aquatic organisms, the ambient water criterion is 0.002 mg/l. The behavior of methylene chloride in a POTW has not been studies in any detail. However, the biochemical oxidation of this conpound was studied in one laboratory scale at concentrations higher than those expected to be contained by most municipal wastewaters. After five days no degradation of methylene chloride was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of methylene choride in a POTW.

The high vapor pressure of methylene chloride is expected to result in volatilization of the compound from aerobic treatment steps in a POTW. It has been reported that methylene chloride inhibits anerobic processes in a POTW. Methylene chloride that is not volatillized in the POTW is expected to pass through into the effluent.

Phthalate Esters (66-71). Phthalic acid, or 1,2-benzenedicarboxylic acid, is one of three isomeric benzenedicarboxylic acids produced by the chemical industry. The other two isomeric forms are called isophthalic and terephthalic acids. The formula for all three acids is $C_6H_4(COOH)_2$. Some esters of phthalic acid are designated as priority pollutants. They will be discussed as a group here, and specific properties of individual phthalate esters will be discussed afterwards.

Over one billion pounds of phthalic acid esters are manufactured in the U.S. annually. They are used as plasticizers - primarily in the production of polyvinyl chloride (PVC) resins. The most widely used phthalate plasticizer is bis (2-ethylhexyl) phthalate (66) which accounts for nearly one third of the phthalate esters produced. This particular ester is commonly referred to as dioctyl phthalate (DOP) and should not be confused with one of the less used esters, di-n-octyl phthalate (69), which is also used as a plasticizer. In addition to these two isomeric dioctyl phthalates, four other esters, also used primarily as plasticizers, are designated as priority pollutants. They are: butyl benzyl phthalate (67); di-n-butyl phthalate (68); diethyl phthalate (70); and dimethyl phthalate (71).

Industrially, phthalate esters are prepared from phthalic anhydride and the specific alcohol to form the ester. Some evidence is available suggesting that phthalic acid esters also may be synthesized by certain plant and animal tissues. The extent to which this occurs in nature is not known.

Phthalate esters used as plasticizers can be present in concentrations of up to 60 percent of the total weight of the PVC plastic. The plasticizer is not linked by primary chemical bonds to the PVC resin. Rather, it is locked into the structure of intermeshing polymer molecules and held by van der Waals forces. The result is that the plasticizer is easily extracted. Plasticizers are responsible for the odor associated with new plastic toys or flexible sheet that has been contained in a sealed package.

Although the phthalate esters are not soluble or are only very slightly soluble in water, they do migrate into aqueous solutions placed in contact with the plastic. Thus industrial facilities with tank linings, wire and cable coverings, tubing, and sheet flooring of PVC are expected to discharge some phthalate esters in their raw waste. In addition to their use as plasticizers, phthalate esters are used in lubricating oils and pesticide carriers. These also can contribute to industrial discharge of phthalate esters.

The accumulated data on acute toxicity in animals suggest that phthalate esters have a rather low order of toxicity. Human toxicity data are limited. It are thought that the toxic effects of the esters is most likely due to one of the metabolic products, in particular the monoester. Oral acute toxicity in animals is greater for the lower molecular weight esters than for the higher molecular weight esters.

Orally administered phthalate esters generally produced enlarging of liver and kidney, and atrophy of testes in laboratory animals. Specific esters produced enlargement of heart and brain, spleenitis, and degeneration of central nervous system tissue.

Subacute doses administered orally to laboratory animals produced some decrease in growth and degeneration of the testes. Chronic studies in animals showed similar effects to those found in acute and subacute studies, but to a much lower degree. The same organs were enlarged, but pathological changes were not usually detected.

A recent study of several phthalic esters produced suggestive but not conclusive evidence that dimethyl and diethyl phthalates have a cancer liability. Only four of the six priority pollutant esters were included in the study. Phthalate esters do biconcentrate in fish. The factors, weighted for relative consumption of various aquatic and marine food groups, are used to calculate ambient water quality criteria for four phthalate esters. The values are included in the discussion of the specific esters.

Studies of toxicity of phthalate esters in freshwater and salt water organisms are scarce. A chronic toxicity test with bis(2-ethylhexyl) phthalate showed that significant reproductive impairment occurred at 0.003 mg/l in the freshwater crustacean, Daphnia magna. In acute toxicity studies, saltwater fish and organisms showed sensitivity differences of up to eight-fold to butyl benzyl, diethyl, and dimethyl phthalates. This suggests that each ester must be evaluated individually for toxic effects.

The behavior of phthalate esters in POTW has not been studied. However, the biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewater. Three of the phthalate esters were studied. Bis(2-ethylhexyl) phthalate was found to be degraded slightly or not at all and its removal by biological treatment in a POTW is expected to be slight or zero. Di-n-butyl phthalate and diethyl phthalate were degraded to a moderate degree and their removal by biological treatment in a POTW is expected to occur to a moderate degree. Using these data and other observations relating molecular structure to ease of biochemical degradation of other organic pollutants, the conclusion was reached that butyl benzyl phthalate and dimethyl phthalate would be removed in a POTW to a moderate degree by biological treatment. On the same basis, it was concluded that di-n-octyl phthalate would be removed to a slight degree or not at all.

No information was found on possible interference with POTW operation or the possible effects on sludge by the phthalate esters. The water insoluble phthalate esters - butyl benzyl and di-n-octyl phthalate - would tend to remain in sludge, whereas the other four priority pollutant phthalate esters with water solubilities ranging from 50 mg/l to 4.5 mg/l would probably pass through into the POTW effluent.

Bis (2-ethylhexyl) phthalate(66). Little information is available about the physical properties of bis(2-ethylhexyl) phthalate. It is a liquid boiling at 387°C at 5mm Hg and is insoluble in water. Its formula is $C_6H_4(COOC_8H_{17})_2$. This priority pollutant constitutes about one third of the phthalate ester production in the U.S. It is commonly referred to as dioctyl phthalate, or DOP, in the plastics industry where it is the most extensively used compound for the plasticization of polyvinyl chloride (PVC). Bis(2-ethylhexyl) phthalate has been approved by the FDA for use in plastics in contact with food. Therefore, it may be found in wastewaters coming in contact with discarded plastic food wrappers as well as the PVC films and shapes normally found in industrial plants. This priority pollutant is also a commonly used organic diffusion pump oil where its low vapor pressure is an advantage.

For the protection of human health from the toxic properties of bis(2-ethylhexyl) phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 15 mg/l.

Although the behavior of bis(2-ethylhexyl) phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. In fresh water with a non-acclimated seed culture, no biochemical oxidation was observed after 5, 10, and 20 days; with an acclimated seed culture, however, biological oxidation of 13, 0, 6, and 23 percent of theoretical occurred after 5, 10, 15 and 20 days, respectively. Bis(2-ethylhexyl) phthalate concentrations were 3 to 10 mg/l. Little or no removal of bis(2-ethylhexyl) phthalate by biological treatment in POTW is expected.

Butyl benzyl phthalate(67). No information was found on the physical properties of this compound.

Butyl benzyl phthalate is used as a plasticizer for PVC. Two special applications differentiate it from other phthalate esters. It is approved by the U.S. FDA for food contact in wrappers and containers; and it is the industry standard for plasticization of vinyl flooring because it provides stain resistance.

No ambient water quality criterion is proposed for butyl benzyl phthalate.

Butyl benzyl phthalate removal in POTW by biological treatment in a POTW is expected to occur to a moderate degree.

Di-n-butyl phthalate (68). Di-n-butyl phthalate (DBP) is a colorless, oily liquid, boiling at 340°C. Its water solubility at room temperature is reported to be 0.4 g/l and 4.5g/l in two different chemistry handbooks. The formula for DBP, $C_6H_4(COOC_4H_9)_2$ is the same as for its isomer, di-isobutyl phthalate. DBP production is one to two percent of total U.S. phthalate ester production.

DBP is used to a limited extent as a plasticizer for polyvinyl chloride (PVC). It is not approved for contact with food. It is used in liquid lipsticks and as a diluent for polysulfide dental impression materials. DBP is used as a plasticizer for nitrocellulose in making gun powder, and as a fuel in solid propellants for rockets. Further uses are insecticides, safety glass manufacture, textile lubricating agents, printing inks, adhesives, paper coatings and resin solvents.

For protection of human health from the toxic properties of dibutyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 34 mg/l.

Although the behavior of di-n-butyl phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. Biochemical oxidation of 35, 43, and 45 percent of theoretical oxidation were obtained after 5, 10, and 20 days, respectively, using sewage microorganisms as an unacclimated seed culture.

Biological treatment in POTW is expected to remove di-n-butyl phthalate to a moderate degree.

Toluene(86). Toluene is a clear, colorless liquid with a benzene-like odor. It is a naturally occuring compound derived primarily from petroleum or petrochemical processes. Some toluene is obtained from the manufacture of metallurgical coke. Toluene is also referred to as toluol, methylbenzene, methacide, and phenylmethane. It is an aromatic hydrocarbon with the formula $C_6H_5CH_3$. It boils at 111°C and has a vapor pressure of 30 mm Hg at room temperature. The water solubility of toluene is 535 mg/l, and it is miscible with a variety of organic solvents. Annual production of toluene in the U.S. is greater than 2 million metric tons. Approximately two-thirds of the toluene is converted to benzene; the remaining 30 percent is divided approximately equally into chemical manufacture and use as a paint solvent and aviation gasoline additive. An estimated 5,000 metric tons is discharged to the environment annually as a constituent in wastewater.

Most data on the effects of toluene in human and other mammals have been based on inhalation exposure or dermal contact studies. There appear to be no reports of oral administration of toluene to human subjects. A long term toxicity study on female rats revealed no adverse effects on growth, mortality, appearance and behavior, organ to body weight ratios, blood-urea nitrogen levels, bone marrow counts, peripheral blood counts, or morphology of major organs. The effects of inhaled toluene on the central nervous system, both at high and low concentrations, have been studied in humans and animals. However, ingested toluene is expected to be handled differently by the body because it is absorbed more slowly and must first pass through the liver before reaching the nervous system. Toluene is extensively and rapidly metabolized in the liver. One of the principal metabolic products of toluene is benzoic acid, which itself seems to have little potential to produce tissue injury.

Toluene does not appear to be teratogenic in laboratory animals or man. Nor is there any conclusive evidence that toluene is mutagenic. Toluene has not been demonstrated to be positive in any *in vitro* mutagenicity or carcinogenicity bioassay system, nor to be carcinogenic in animals or man.

Toluene has been found in fish caught in harbor waters in the vicinity of petroleum and petrochemical plants. Bioconcentration studies have not been conducted, but bioconcentration factors have been calculated on the basis of the octanol-water partition coefficient.

For the protection of human health from the toxic properties of toluene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l. If contaminated aquatic organisms alone are consumed excluding the consumption of water, the ambient water criterion is 424 mg/l. Available data show that the adverse effects on aquatic life occur at concentrations as low as 5 mg/l.

Acute toxicity tests have been conducted with toluene and a variety of freshwater fish and Daphnia magna. The latter appears to be significantly more resistant than fish. No test results have been reported for the chronic effects of toluene on freshwater fish or invertebrate species.

No detailed study of toluene behavior in POTW is available. However, the biochemical oxidation of many of the priority pollutants has been investigated in laboratory scale studies at concentrations greater than those expected to be contained by most municipal wastewaters. At toluene concentrations ranging from 3 to 250 mg/l biochemical oxidation proceeded to fifty percent of theoretical oxidation or greater. The time period varied from a few hours to 20 days, depending on whether or not the seed culture was acclimated. Phenol adapted acclimated seed cultures gave the most rapid and extensive biochemical oxidation. The conclusion reached by study of the limited data is that biological treatment produces moderate removal of toluene in POTW. The volatility and relatively low water solubility of toluene lead to the expectation that aeration processes will remove significant quantities of toluene from the POTW. The EPA studied toluene removal in seven POTW facilities. The removals ranged from 40 to 100 percent. Sludge concentrations of toluene ranged from 54×10^{-3} to 1.85 mg/l.

Arsenic (115). Arsenic (chemical symbol As), is classified as a non-metal or metalloid. Elemental arsenic normally exists in the alpha-crystalline metallic form which is steel gray and brittle, and in the beta form which is dark gray and amorphous. Arsenic sublimes at 615°C. Arsenic is widely distributed throughout the world in a large number of minerals. The most important commercial source of arsenic is as a by-product from treatment of copper, lead, cobalt, and gold ores. Arsenic is usually marketed as the trioxide (As_2O_3). Annual U.S. production of the trioxide approaches 40,000 tons.

The principal use of arsenic is in agricultural chemicals (herbicides) for controlling weeds in cotton fields. Arsenicals have varioys applications in medicinal and vetrinary use, as wood preservatives, and in semicconductors.

The effects of arsenic in humans were known by the ancient Greeks and Romans. The principal toxic effects are gastrointestinal disturbances. Breakdown of red blood cells occurs. Symptoms of acute poisoning include vomiting, diarrhea, abdominal pain, lassitude, dizziness, and headache. Longer exposure produced dry, falling hair, brittle, losse nails, eczena, and exfoliation. Arsenicals also exhibit teratogenic and mutagenic effects in humans. Oral administration of arsenic compounds has been associated clinically with skin cancer for nearly one hundred years. Since 1888 numerous studies have linked occupational exposure and therapeutic administration of arsenic compounds to increased incidence of respiratory and skin cancer.

For the maximum protection of human health from the potential carcinogenic effects of exposure to arsenic through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of arsenic estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 2.2×10^{-7} mg/l, 2.2×10^{-6} mg/l, and 2.2×10^{-5} mg/l. respectively. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 1.75×10^{-4} to keep the increased lifetime cancer risk below 10^{-5}. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited fro human health risks.

A few studies have been made regarding the behavior of arsenic in a POTW. One EPA survey of nine POTW facilities reported influent concentrations ranging from 0.0005 to 0.693 mg/l; effluents from three a POTW having biological treatment contained 0.0004 to 0.01 mg/l; two POTW facilities showed arsenic removal efficiencies of 50 and 71 percent in biological treatment. Inhibition of treatment processes by sodium arsenate is reported to occur at 0.1 mg/l in activated sludge, and 1.6 mg/l in in anaerobic digestion processes. In another study based on data from 60 POTW facilities, arsenic in sludge ranged from 1.6 to 65.5 mg/kg and the median value was 7.8 mg/kg. Arsenic in sludge spread on cropland may be taken up by plants grown on that land. Edible plants can take up arsenic, but normally their growth is inhibited before the plants are ready for harvest.

Cadmium (118). Cadmium is a relatively rare metallic element that is seldom found in sufficient quantities in a pure state to warrent mining or extraction from the earth's surface. It is found in trace amounts of about 1 ppm throughout the earth's crust. Cadmium is, however, a valuable by-product of zinc production.

Cadmium is used primarily as an electroplated metal, and is found as an impurity in the secondary refining of zinc, lead, and copper.

Cadmium is an extremely dangerous cumulative toxicant, causing progressive chronic poisoning in mammals, fish, and probably other organisms. The metal is not excreted.

Toxic effects of cadmium on man have been reported from throughout the world. Cadmium may be a factor in the development of such human pathological conditions as kidney disease, testicular tumors, hypertension, arteriosclerosis, growth inhibition, chronic disease of old age, and cancer. Cadmium is normally ingested by humans through food and water as well as by breathing air contaminated by cadmium dust. Cadmium is cumulative in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome known as itai-itai disease has been documented in Japan as caused by cadmium ingestion via drinking water and contaminated irrigation water. Ingestion of as little as 0.6 mg/day has produced the disease. Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity.

Cadmium is concentrated by marine organisms, particularly molluscs, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1000 for cadmium in fish muscle has been reported, as have concentration factors of 3000 in marine plants and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more sensitive than fish eggs and larvae.

For the protection of human health from the toxic properties of cadmium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l.

Cadmium is not destroyed when it is introduced into a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. In addition, it can interfere with the POTW treatment process.

In a study of 189 POTW, 75 percent of the primary plants, 57 percent of the trickling filter plants, 66 percent of the activated sludge plants and 62 percent of the biological plants allowed over 90 percent of the influent cadmium to pass through to the POTW effluent. Only 2 of the 189 POTW allowed less than 20 percent pass-through, and none less than 10 percent pass-through. POTW effluent concentrations ranged from 0.001 to 1.97 mg/l (mean 0.028 mg/l, standard deviation 0.167 mg/l).

Cadmium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Cadmium contamination of sewage sludge limits its use on land since it increases the level of cadmium in the soil. Data show that cadmium can be incorporated into crops, including vegetables and grains, from contaminated soils. Since the crops themselves show no adverse effects from soils with levels up to 100 mg/kg cadmium, these contaminated crops could have a significant impact on human health. Two Federal agencies have already recognized the potential adverse human health effects posed by the use of sludge on cropland. The FDA recommends that sludge containing over 30 mg/kg of cadmium should not be used on agricultural land. Sewage sludge contains 3 to 300 mg/kg (dry basis) of cadmium mean = 10 mg/kg; median = 16 mg/kg. The USDA also recommends placing limits on the total cadmium from sludge that may be applied to land.

Chromium(119). Chromium is an elemental metal usually found as a chromite ($FeO \cdot Cr_2O_3$). The metal is normally produced by reducing the oxide with aluminum. A significant proportion of the chromium used is in the form of compounds such as sodium dichromate (Na_2CrO_4), and chromic acid (CrO_3) - both are hexavalent chromium compounds.

Chromium and its compounds are used extensively in the canmaking subcategory of the coil coating industry. As the metal, it is found as an alloying component of many steels.

The two chromium forms most frequently found in industry wastewaters are hexavalent and trivalent chromium. Hexavalaent chromium is the form used for metal treatments. Some of it is reduced to trivalent chromium as part of the process reaction. The raw wastewater containing both valence states is usually treated first to reduce remaining hexavalent to trivalent chromium, and second to precipitate the trivalent form as the hydroxide. The hexavalent form is not removed by lime treatment.

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled, and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Hexavalent chromium is a known human carcinogen. Levels of chromate ions that show no effect in man appear to be so low as to prohibit determination, to date.

The toxicity of chromium salts to fish and other aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic effects, especially the effect of water hardness. Studies have shown that trivalent chromium is more toxic to fish of some types than is hexavalent chromium. Hexavalent chromium retards growth of one fish species at 0.0002 mg/l. Fish food organisms and other lower forms of aquatic life are extremely sensitive to chromium. Therefore, both hexavalent and trivalent chromium must be considered harmful to particular fish or organisms.

For the protection of human health from the toxic properties of chromium (except hexavalent chromium) ingested through water and contaminated aquatic organisms, the recommended water qualtiy criterion is 170 mg/l.

For the protection of human health from the toxic effects of exposure to hexavalent chromium through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero.

Chromium is not destroyed when treated by POTW (although the oxidation state may change), and will either pass through to the POTW effluent or be incorporated into the POTW sludge. Both oxidation states can inhibit POTW treatment and can also limit the usefuleness of municipal sludge.

EPA has observed influent concentrations of chromium to POTW facilities to range from 0.005 to 14.0 mg/l, with a median concentration of 0.1 mg/l. The efficiencies for removal of chromium by the activated sludge process can vary greatly, depending on chromium concentration in the influent, and other operating conditions at the POTW. Chelation of chromium by organic matter and dissolution due to the presence of carbonates can cause deviations from the predicted behavior in treatment systems.

The systematic presence of chromium compounds will halt nitrification in a POTW for short periods, and most of the chromium will be retained in the sludge solids. Hexavalent chromium has been reported to severely affect the nitrification process, but trivalent chromium has little or no toxicity to activated sludge, except at high concentrations. The presence of iron, copper, and low pH will increase the toxicity of chromium in a POTW by releasing the chromium into solution to be ingested by microorganisms in the POTW.

The amount of chromium which passes through to the POTW effluent depends on the type of treatment processes used by the POTW. In a study of 240 POTW's, 56 percent of the primary plants allowed more than 80 percent pass through to POTW effluent. More advanced treatment results in less pass-through. POTW effluent concentrations ranged from 0.003 to 3.2 mg/l total chromium (mean = 0.197, standard deviation = 0.48), and from 0.002 to 0.1 mg/l hexavalent chromium (mean = 0.017, standard deviation = 0.020).

Chromium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Sludge concentrations of total chromium of over 20,000 mg/kg (dry basis) have been observed. Disposal of sludges containing very high concentrations of trivalent chromium can potentially cause problems in uncontrollable landfills. Incineration, or similar destructive oxidation processes can produce hexavalent chromium from lower valance states. Hexavalent chromium is potentially more toxic than trivalent chromium. In cases where high rates of chrome sludge application on land are used, distinct growth inhibition and plant tissue uptake have been noted.

Pretreatment of discharges substantially reduces the concentration of chromium in sludge. In Buffalo, New York, pretreatment of electroplating waste resulted in a decrease in chromium concentrations in POTW sludge from 2,510 to 1,040 mg/kg. A similar reduction occurred in a Grand Rapids, Michigan, POTW where the chromium concentration in sludge decreased from 11,000 to 2,700 mg/kg when pretreatment was required.

Copper(120). Copper is a metallic element that sometimes is found free, as the native metal, and is also found in minerals such as cuprite (Cu_2O), malechite [$CuCO_3 \bullet Cu(OH)_2$], azurite [$2CuCO_3 \bullet Cu(OH)_2$], chalcopyrite ($CuFeS_2$), and bornite (Cu_5FeS_4). Copper is obtained from these ores by smelting, leaching, and electrolysis. It is used in the plating, electrical, plumbing, and heating equipment industries, as well as in insecticides and fungicides. In the canmaking subcategory of the coil coating industry copper can be attributed to various contaminant sources.

Traces of copper are found in all forms of plant and animal life, and the metal is an essential trace element for nutrition. Copper is not considered to be a cumulative systemic poison for humans because it is readily excreted by the body, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, at relatively low dosages. The limiting factor in domestic water supplies is taste. To prevent this adverse organoleptic effect of copper in water, a criterion of 1 mg/l has been established.

The toxicity of copper to aquatic organisms varies significantly, not only with the species, but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts may be reduced by the precipitation of copper carbonate or other insoluble compounds. The sulfates of copper and zinc, and of copper and calcium are synergistic in their toxic effect on fish.

Relatively high concentrations of copper may be tolerated by adult fish for short periods of time; the critical effect of copper appears to be its higher toxicity to young or juvenile fish. Concentrations of 0.02 to 0.031 mg/l have proved fatal to some common fish species. In general the salmonoids are very sensitive and the sunfishes are less sensitive to copper.

The recommended criterion to protect saltwater aquatic life is 0.004 mg/l as a 24-hour average, and 0.023 mg/l maximum concentration.

Copper salts cause undesirable color reactions in the food industry and cause pitting when deposited on some other metals such as aluminum and galvanized steel.

Irrigation water containing more than minute quantities of copper can be detrimental to certain crops. Copper appears in all soils, and its concentration ranges from 10 to 80 ppm. In soils, copper occurs in association with hydrous oxides of manganese and iron, and also as soluble and insoluble complexes with organic matter. Copper is essential to the life of plants, and the normal range of concentration in plant tissue is from 5 to 20 ppm. Copper concentrations in plants normally do not build up to high levels when toxicity occurs. For example, the concentrations of copper in snapbean leaves and pods was less than 50 and 20 mg/kg, respectively, under conditions of severe copper toxicity. Even under conditions of copper toxicity, most of the excess copper accumulates in the roots; very little is moved to the aerial part of the plant.

Copper is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with the POTW treatment processes and can limit the usefulness of municipal sludge.

The influent concentration of copper to POTW facilities has been observed by the EPA to range from 0.01 to 1.97 mg/l, with a median concentration of 0.12 mg/l. The copper that is removed from the influent stream of a POTW is adsorbed on the sludge or appears in the sludge as the hydroxide of the metal. Bench scale pilot studies have shown that from about 25 percent to 75 percent of the copper passing through the activated sludge process remains in solution in the final effluent. Four-hour slug dosages of copper sulfate in concentrations exceeding 50 mg/l were reported to have severe effects on the removal efficiency of an unacclimated system, with the system returning to normal in about 100 hours. Slug dosages of copper in the form of copper cyanide were observed to have much more severe effects on the activated sludge system, but the total system returned to normal in 24 hours.

In a recent study of 268 POTW, the median pass-through was over 80 percent for primary plants and 40 to 50 percent for trickling filter, activated sludge, and biological treatment plants. POTW effluent concentrations of copper ranged from 0.003 to 1.8 mg/l (mean 0.126, standard deviation 0.242).

Copper which does not pass through the POTW will be retained in the sludge where it will build up in concentration. The presence of excessive levels of copper in sludge may limit its use on cropland. Sewage sludge contains up to 16,000 mg/kg of copper, with 730 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which usually range from 18 to 80 mg/kg. Experimental data indicate that when dried sludge is spread over tillable land, the copper tends to remain in place down to the depth of tillage, except for copper which is taken up by plants grown in the soil. Recent investigation has shown that the extractable copper content of sludge-treated soil decreased with time, which suggests a reversion of copper to less soluble forms was occurring.

Cyanide(121).

Cyanides are among the most toxic of pollutants commonly observed in industrial wastewaters. Introduction of cyanide into industrial processes is usually by dissolution of potassium cyanide (KCN) or sodium cyanide (NaCN) in process waters; however, the hydrogen cyanide (HCN) formed when the above salts are dissolved in water is probably the most acutely lethal compound.

The relationslhip of pH to hydrogen cyanide formation is very important. As pH decreases below 7, more than 99 percent of the cyanide is present as HCN and less than 1 percent as cyanide ions. Thus, at neutral pH, that of most living organisms, the more toxic form of cyanide prevails.

Cyanide ions combine with numerous heavy metal ions to form complexes. The complexes are in equilibrium with HCN. Thus, the stability of the metal-cyanide complex and the pH determine the concentration of HCN. Stability of the metal-cyanide anion complexes is extremely variable. Those formed with zinc, copper, and cadmium are not stable - they rapidly dissociate, with production of HCN, in near neutral or acid waters. Some of the complexes are extremely stable. Cobaltocyanide is very resistant to acid distillation in the laboratory. Iron cyanide complexes are also stable, but undergo photodecomposition to give HCN upon exposure to sunlight. Synergistic effects have been demonstrated for the metal cyanide complexes making zinc, copper, and cadmium cyanides more toxic than an equal concentration of sodium cyanide.

The toxic mechanism of cyanide is essentially an inhibition of oxygen metabolism, i.e., rendering the tissues incapable of exchanging oxygen. The cyanogen compounds are true noncumulative protoplasmic poisons. They arrest the activity of all forms of animal life. Cyanide shows a very specific type of toxic action. It inhibits the cytochrome oxidase system. This system is the one which facilitates electron transfer from reduced metabolites to molecular oxygen. The human body can convert cyanide to a non-toxic thiocyanate and eliminate it. However, if the quantity of cyanide ingested is too great at one time, the inhibition of oxygen utilization proves fatal before the detoxifying reaction reduces the cyanide concentration to a safe level.

Cyanides are more toxic to fish than to lower forms of aquatic organisms such as midge larvae, crustaceans, and mussels. Toxicity to fish is a function of chemical form and concentration, and is influenced by the rate of metabolism (temperature), the level of dissolved oxygen, and pH. In laboratory studies free cyanide concentrations ranging from 0.05 to 0.15 mg/l have been proven to be fatal to sensitive fish species including trout, bluegill, and fathead minnows. Levels above 0.2 mg/l are rapidly fatal to most fish species. Long term sublethal concentrations of cyanide as low as 0.01 mg/l have been shown to affect the ability of fish to function normally, e.g., reproduce, grow, and swim.

For the protection of human health from the toxic properties of cyanide ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.200 mg/l.

Persistance of cyanide in water is highly variable and depends upon the chemical form of cyanide in the water, the concentration of cyanide, and the nature of other constituents. Cyanide may be destroyed by strong oxidizing agents such as permanganate and chlorine. Chlorine is commonly used to oxidize strong cyanide solutions. Carbon dioxide and nitrogen are the products of complete oxidation. But if the reaction is not complete, the very toxic compound; cyanogen chloride may remain in the treatment system and subsequently be released to the environment. Partial chlorination may occur as part of a POTW treatment, or during the disinfection treatment of surface water for drinking water preparation.

Cyanides can interfere with treatment processes in POTW, or pass through to ambient waters. At low concentrations and with acclimated microflora, cyanide may be decomposed by microorganisms in anaerobic and aerobic environments or waste treatment systems. However, data indicate that much of the cyanide introduced passes through to the POTW effluent. The mean pass-through of 14 biological plants was 71 percent. In a recent study of 41 POTW, the effluent concentrations ranged from 0.002 to 100 mg/l (mean = 2.518, standard deviation = 15.6). Cyanide also enhances the toxicity of metals commonly found in POTW effluents, including the priority pollutants cadmium, zinc, and copper.

Data for Grand Rapids, Michigan, showed a significant decline in cyanide concentrations downstream from the POTW after pretreatment regulations were put in force. Concentrations fell from 0.66 mg/l before, to 0.01 mg/l after pretreatment was required.

Lead (122). Lead is a soft, malleable ductible, bluish-gray, metallic element, usually obtained from the mineral galena (lead sulfide, PbS), anglesite (lead sulfate, $PbSO_4$), or cerussite (lead carbonate, $PbCO_3$). Because it is usually associated with the minerals zinc, silver, copper, gold, cadmium, antimony, and arsenic, special purification methods are frequently used before and after extraction of the metal from the ore concentrate by smelting.

Lead is widely used for its corrosion resistance, sound and vibration absorption, low melting point (solders), and relatively high imperviousness to various forms of radiation. Small amounts of copper, antimony and other metals can be alloyed with lead to achieve greater hardness, stiffness, or corrosion resistance than is afforded by the pure metal. Lead compounds are used in glazes and paints. About one third of U.S. lead consumption goes into storage batteries. About half of U.S. lead consumption is from secondary lead recovery. U.S. consumption of lead is in the range of one million tons annually.

Lead ingested by humans produces a variety of toxic effects including impaired reproductive ability, disturbances in blood chemistry, neurological disorders, kidney damage, and adverse cardiovascular effects. Exposure to lead in the diet results in permanent increase in lead levels in the body. Most of the lead entering the body eventually becomes localized in the bones where it accumulates. Lead is a carcinogen or cocarcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. Mutangenicity data are not available for lead.

For the protection of human health from the toxic properties of lead ingested through water and through contaminated aquatic organisms, the ambient water criterion is 0.050 mg/l.

Lead is not destroyed in POTW, but is passed through to the effluent or retained in the POTW sludge; it can interfere with POTW treatment processes and can limit the usefulness of POTW sludge for application to agricultural croplands. Threshold concentration for inhibition of the activated sludge process is 0.1 mg/l, and for the nitrification process is 0.5 mg/l. In a study of 214 POTW, median pass through values were over 80 percent for primary plants and over 60 percent for trickling filter, activated sludge, and biological process plants. Lead concentration in POTW effluents ranged from 0.003 to 1.8 mg/l (means = 0.106 mg/l, standard deviation = 0.222).

Application of lead-containing sludge to cropland should not lead to uptake by crops under most conditions because normally lead is strongly bound by soil. However, under the unusual conditions of low pH (less than 5.5) and low concentrations of labile phosphorus, lead solubility is increased and plants can accumulate lead.

Mercury (123). Mercury is an elemental metal rarely found in nature as the free metal. Mercury is unique among metals as it remains a liquid down to about 39 degrees below zero. It is relatively inert chemically and is insoluble in water. The principal ore is cinnabar (HgS).

Mercury is used industrially as the metal and as mercurous and mercuric salts and compounds. Mercury is used in several types of batteries. Mercury released to the aqueous environment is subject to biomethylation - conversion to the extremely toxic methyl mercury.

Mercury can be introduced into the body through the skin and the respiratory system as the elemental vapor. Mercuric slats are highly toxic to humans and can be absorbed through the gastro-intestinal tract. Fatal does can vary from 1 to 30 grams. Chronic toxicity of methyl mercury is evidenced primarily by neurological symptoms. Some mercuric salts cuase death by kidney failure.

Mercuric salts are extremely toxic to fish and other aquatic life. Mercuric chloride is more lethal than copper, hexavalent chromiun, zinc, nickel, and lead towards fish and aquatic life. In the food cycle, algae containing mercury up to 100 times the concnetration in the surrouding sea water are eaten by fish which further concentrate the mercury. Predators that eat the fish in turn concentrate the mercury even further.

For the protection of human health from the toxic properties of mercury ingested through water and through contaminated aquatic organisms the ambient water criterion is determined to be 0.0002 mg/l.

Mercury is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. at low concentrations it may reduce POTW removal efficiencies, and at high concentrations it may upset the POTW operation.

The influent concentrations of mercury to a POTW have been observed by the EPA to range from 0.002 to 0.24 mg/l, with a median concentration of 0.001 mg/l. Mercury has been reported in the literature to have inhibiting effects upon an activated sludge POTW at levels as low as 0.1 mg/l. At 5 mg/l of mercury, losses of COD removal efficiency of 14 to 40 percent have been reported, while at 10 mg/l loss of removal of 59 percent has been reported. Upset of an activated sludge POTW is reported in the literature to occur near 200 mg/l. The anaerobic digestion process is much less affected by the presence of mercury, with inhibitory effects being reported at 1,365 mg/l.

In a study of 22 POTW facilities having secondary treatment, the range of removal of mercury from the influent to the POTW ranged from 4 to 99 percent with median removal of 41 percent. THus significant pass through of mercury may occur.

In sludges, mercury content may be high if industrial sources of mercury contamination are present. LIttle is known about the form in which mercury occurs in sludge. Mercury may undergo biological methylation in sediments, but no methylation has been observed in soils, mud, or sewage sludge.

The mercury content of soils not receiving additions of POTW sewage sludge lie in the range from 0.01 to 0.5 mg/kg. In soils receiving POTW sludges for protracted periods, the concentration of mercury has been observed to approach 1.0 mg/kg. In the soil, mercury enters into reactions with the exchange complex of clay and organic fractions, forming both ionic and covalent bonds. CHemical and microbiological degradation of mercurials can take place side by side in the soil, and the products - ionic or molecular - are retained by organic matter and clay or may be volatilized if gaseous. Because of the high affinity between mercury and the solid soil surfaces, mercury persists in the upper layer of the soil.

Mercury can enter plants through the roots, it can readily move to other parts of the plant, and it has been reported to cuase injury to plants. In many plants mercury concentrations range from 0.01 to 0.20 mg/kg, but when plants are supplied with high levels of mercury, these concentrations can exceed 0.5 mg/kg. Bioconcnetration occurs in animals ingesting mercury in food.

Nickel(124). Nickel is seldom found in nature as the pure elemental metal. It is a reltively plentiful element and is widely distributed throughout the earth's crust. It occurs in marine organisms and is found in the oceans. The chief commercial ores for nickel are pentlandite $[(Fe,Ni)_9S_8]$, and a lateritic ore consisting of hydrated nickel-iron-magnesium silicate.

Nickel has many and varied uses. It is used in alloys and as the pure metal. Nickel salts are used for electroplating baths. The coil coating industry uses nickel compounds as accelerators in certain conversion coating solutions. Nickel is also found as a contaminant in mineral acids.

The toxicity of nickel to man is thought to be very low, and systemic poisoning of human beings by nickel or nickel salts is almost unknown. In non-human mammals nickel acts to inhibit insulin release, depress growth, and reduce cholesterol. A high incidence of cancer of the lung and nose has been reported in humans engaged in the refining of nickel.

Nickel salts can kill fish at very low concentrations. However, nickel has been found to be less toxic to some fish than copper, zinc, and iron. Nickel is present in coastal and open ocean water at concentrations in the range of 0.0001 to 0.006 mg/l although the most common values are 0.002 - 0.003 mg/l. Marine animals contain up to 0.4 mg/l and marine plants contain up to 3 mg/l. Higher nickel concentrations have been reported to cause reduction in photosynthetic activity of the giant kelp. A low concentration was found to kill oyster eggs.

For the protection of human health based on the toxic properties of nickel ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.0134 mg/l.

Nickel is not destroyed when treated in a POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with POTW treatment processes and can also limit the usefulness of municipal sludge.

Nickel salts have caused inhibition of the biochemical oxidation of sewage in a POTW. In a pilot plant, slug doses of nickel significantly reduced normal treatment efficiencies for a few hours, but the plant acclimated itself somewhat to the slug dosage and appeared to achieve normal treatment efficiencies within 40 hours. It has been reported that the anaerobic digestion process is inhibited only by high concentrations of nickel, while a low concentration of nickel inhibits the nitrification process.

EPA has observed influent concentration of nickel to POTW facilities ranging from 0.01 to 3.19 mg/l, with a median of 0.33 mg/l. In a study of 190 POTW, nickel pass-through was greater than 90 percent for 82 percent of the primary plants. Median pass-through for trickling filter, activated sludge, and biological process plants was greater than 80 percent. POTW effuent concentrations ranged from 0.002 to 40 mg/l (mean = 0.410, standard deviation = 3.279).

Nickel not passed through the POTW will be incorporated into the sludge. In a recent two-year study of eight cities, four of the cities had median nickel concentrations of over 350 mg/kg, and two were over 1,000 mg/kg. The maximum nickel concentration observed was 4,010 mg/kg.

Nickel is found in nearly all soils, plants, and waters. Nickel has no known essential function in plants. In soils, nickel typically is found in the range from 10 to 100 mg/kg. Various environmental exposures to nickel appear to correlate with increased incidence of tumors in man. For example, cancer in the maxillary antrum of snuff users may result from using plant material grown on soil high in nickel.

Nickel toxicity may develop in plants from application of sewage sludge on acid soils. Nickel has reduced yields for a variety of crops, including oats, mustard, turnips, and cabbage. In one study, nickel decreased the yields of oats significantly at 100 mg/kg.

Whether nickel exerts a toxic effect on plants depends on several soil factors, the amount of nickel applied, and the contents of other metals in the sludge. Unlike copper and zinc, which are more available from inorganic sources than from sludge, nickel uptake by plants seems to be promoted by the presence of the organic matter in sludge. Soil treatments such as liming reduce the solubility of nickel. Toxicity of nickel to plants is enhanced in acidic soils.

Zinc(128). Zinc occurs abundantly in the earth's crust, concentrated in ores. It is readily refined into the pure, stable, silvery-white metal. In addition to its use in alloys, zinc is used as a protective coating on steel. It is applied by hot dipping (i.e. dipping the steel in molten zinc) or by electroplating.

Zinc can have an adverse effect on man and animals at high concentrations. Zinc at concentrations in excess of 5 mg/l causes an undesirable taste which persists through conventional treatment. For the prevention of adverse effects due to these organoleptic properties of zinc, 5 mg/l was adopted for the ambient water criterion.

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Lethal concentrations in the range of 0.1 mg/l have been reported. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds cause general enfeeblement and widespread histological changes to many organs, but not to gills. Abnormal swimming behavior has been reported at 0.04 mg/l. Growth and maturation are retarded by zinc. It has been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated water may die as long as 48 hours after removal.

In general, salmonoids are most sensitive to elemental zinc in soft water; the rainbow trout is the most sensitive in hard waters. A complex relationship exists between zinc concentration, dissolved zinc concentration, pH, temperature, and calcium and magnesium concentration. Prediction of harmful effects has been less than reliable and controlled studies have not been extensively documented.

The major concern with zinc compounds in marine waters is not with acute lethal effects, but rather with the long-term sublethal effects of the metallic compounds and complexers. Zinc accumulates in some marine species, and marine animals contain zinc in the range of 6 to 1500 mg/kg. From the point of view of acute lethal effects, invertebrate marine animals seem to be the most sensitive organism tested.

Toxicities of zinc in nutrient solutions have been demonstrated for a number of plants. A variety of fresh water plants tested manifested harmful symptoms at concentrations of 10 mg/l. Zinc sulfate has also been found to be lethal to many plants and it could impair agricultural uses of the water.

Zinc is not destroyed when treated by POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with treatment processes in the POTW and can also limit the usefuleness of municipal sludge.

In slug doses, and particularly in the presence of copper, dissolved zinc can interfere with or seriously disrupt the operation of POTW biological processes by reducing overall removal efficiencies, largely as a result of the toxicity of the metal to biological organisms. However, zinc solids in the form of hydroxides or sulfides do not appear to interfere with biological treatment processes, on the basis of available data. Such solids accumulate in the sludge.

The influent concentrations of zinc to POTW facilities has been observed by the EPA to range from 0.017 to 3.91 mg/l, with a median concentration of 0.33 mg/l. Primary treatment is not efficient in removing zinc; however, the microbial floc of secondary treatment readily adsorbs zinc.

In a study of 258 POTW, the median pass-through values were 70 to 88 percent for primary plants, 50 to 60 percent for trickling filter and biological process plants, and 30-40 percent for activated process plants. POTW effluent concentrations of zinc ranged from 0.003 to 3.6 mg/l (mean = 0.330, standard deviation = 0.464).

The zinc which does not pass through the POTW is retained in the sludge. The presence of zinc in sludge may limit its use on cropland. Sewage sludge contains from 72 to over 30,000 mg/kg of zinc, with 3,366 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which range from 0 to 195 mg/kg, with 94 mg/kg being a common level. Therefore, application of sewage sludge to soil will generally increase the concentration of zinc in the soil. Zinc can be toxic to plants, depending upon soil pH. Lettuce, tomatoes, turnips, mustard, kale, and beets are especially sensitive to zinc contamination.

Aluminum. Aluminum is a non-conventional pollutant. It is a silvery white metal, very abundant in the earth's crust (8.1%), but never found free in nature. Its principal ore is bauxite. Aluminum is produced by electrolysis of this melt. Alumina (Al_2O_3) is extracted from the bauxite and dissolved in molten cryolite.

Aluminum is light, malleable, ductile, possesses high thermal and electrical conductivity, and is non-magnetic. It can be formed, machined or cast. Aluminum is used in the construction, transportation, and container industries and competes with iron and steel in these markets.

Aluminum has been found to be toxic to freshwater and marine aquatic life. In freshwaters acute toxicity and solubility increases as pH levels increase above pH 7. This relationship also appears to be true as the pH levels decrease below pH 7. Chronic effects of aluminum on aquatic life have also been documented. Aluminum has been found to be toxic to certain plants. A water quality standard for aluminum was established (U.S. Federal Water Pollution Control Administration, 1968) for interstate agricultural and irrigation waters, which set a trace element tolerance at 1 mg/l for continuous use on all soils and 20 mg/l for short term use on fine-textured soils.

Aluminum and some of its compounds used in food preparation and as food additives are generally recognized as safe and are sanctioned by the Food and Drug Administration. No limits on aluminum content in food and beverage products have been established.

There are no reported adverse physiological effects on man from low concentrations of aluminum in drinking water, however, large concentrations of aluminum in the human body are alleged to cause changes in behavior. Salts of aluminum are used as coagulants in water treatment, and in limited quantities do not have any adverse effects on POTW operations. Some aluminum salts are soluble, however, mildly alkaline conditions cause precipitation of aluminum as hydroxide. The precipitation of aluminum hydroxide can have an adverse effect on rooted aquatics and invertebrate benthos.

Fluoride. Fluoride is a traditional pollutant. Fluoride is the anionic form of fluorine a highly reactive gas which exists in the elemental state only under carefully controlled conditions. Hydrofluoric acid is commonly used as an etchant to provide proper surface texture for application of other materials.

Although fluoride is not listed as a priority pollutant, it can be toxic to livestock and plants, and can cause tooth mottling in humans. The National Academy of Sciences recommends: (1) two milligrams per liter as an upper limit for watering livestock and, (2) one milligram per liter for continuous use as irrigation water on acid soils to prevent plant toxicity and reduced crop yield. Although some fluoride in drinking water helps to prevent tooth decay, EPA's National Interim Primary Drinking Water Regulations set limitations of 1.4 to 2.4 milligrams per liter in drinking water to protect against tooth molling.

Phenols(Total). Total phenols is the result of analysis using the 4-AAP (4-aminoantipyrene) method. This analytical procedure measures the color development of reaction products between 4-AAP and some phenols. The results are reported as phenol. Thus "total phenol" is not total phenols because many phenols (notably nitrophenols) do not react. Also, since each reacting phenol contributes to the color development to a different degree, and each phenol has a molecular weight different from others and from phenol itself, analyzes of several mixtures containing the same total concentration in mg/l of several phenols will give different numbers depending on the proportions in the particular mixture.

Despite these limitations of the analytical method, total phenols is a useful parameter when the mix of phenols is relatively constant and an inexpensive monitoring method is desired. In any given plant or even in an industry subcategory, monitoring of "total phenols" provides an indication of the concentration of this group of priority pollutants as well as those phenols not selected as priority pollutants. A further advantage is that the method is widely used in water quality determinations.

In an EPA survey of 103 POTW the concentration of "total phenols" ranged from 0.0001 mg/l to 0.176 mg/l in the influent, with a median concentration of 0.016 mg/l. Analysis of effluents from 22 of these same POTW which had biological treatment meeting secondary treatment performance levels showed "total phenols" concentrations ranging from 0 mg/l to 0.203 mg/l with a median of 0.007. Removals were 64 to 100 percent, with a median of 78 percent.

It must be recognized, however, that six of the eleven priority pollutant phenols could be present in high concentrations and not be detected. Conversely, it is possible, but not probable, to have a high "total phenol" concentration without any phenol itself or any of the ten other priority pollutant phenols present. A characterization of the phenol mixture to be monitored to establish constancy of composition will allow "total phenols" to be used with confidence.

Phosphorus. Phosphorus, a traditional pollutant, is a general term used to designate the various anions containing pentavalent phosphorus and oxygen - orthophosphate $[(PO_4)^{-3}]$, metaphosphate $[(PO_3)^{-}]$, pyrophosphate $[(P_2O_7{}^{-4}]$, hypophosphate $[(P_2O_6)^{-4}]$. The element phosphorus exists in several allotropic forms - red, white or yellow, and black. White phosphorus reacts with oxygen in air, igniting spontaneously. It is not found free in nature, but is widely distributed in nature. The most important commercial sources of phosphate are the apatites $[3Ca_3(PO_4)_2{\bullet}CaF_2$ and $3Ca_3(PO_4)_2{\bullet}CaCl_2]$. Phosphates also occur in bone and other tissue. Phosphates are essential for plant and animal life. Several millions of tons of phosphates are mined and converted for use each year in the U.S. The major form produced is phosphoric acid. The acid is then used to produce other phosphate chemicals.

The largest use for phosphates is fertilizer. Most of the U.S. production of phosphoric acid goes into that application. Phosphates are used in cleaning preparations for household and industrial applications and as corrosion inhibitors in boiler feed water and cooling towers.

Phosphates are not controlled because of toxic effects on man. Phosphates are controlled because they promote growth of algae and other plant life in aquatic environments. Such growth first becomes unsightly; if it flourishes, it eventually dies and adds to the BOD. The result can be a dead body of water. No standards or criteria appear to have been established for U.S. surface waters.

Phosphorus is one of the concerns of any POTW, because phosphates are introduced into domestic wastewaters from human body wastes and food wastes as well as household detergents. About ten percent of the phosphorus entering POTW is insoluble and is removed by primary settling. Biological treatment removes very little of the remaining phosphate. Removal is accomplished by forming an insoluble precipitate which will settle out. Alum, lime, and ferric chloride or sulfate are commonly used for this purpose. The point of addition of chemicals for phosphate removal requires careful evaluation because pH adjustment may be required, and material and capital costs differ with different removal schemes. The phosphate content of the effluent also varies according to the scheme used. There is concern about the effect of phosphate contained in sludge used for soil amendment. Phosphate is a principal ingredient of fertilizers.

Oil and Grease. Oil and grease are taken together as one pollutant parameter. This is a conventional pollutant and some of its components are:

1. Light Hydrocarbons - These include light fuels such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these light hydrocarbons may make the removal of other heavier oil wastes more difficult.

2. Heavy Hydrocarbons, Fuels, and Tars - These include the crude oils, diesel oils, #6 fuel oil, residual oils, slop oils, and in some cases, asphalt and road tar.

3. Lubricants and Cutting Fluids - These generally fall into two classes: non-emulsifiable oils such as lubricating oils and greases and emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds. Emulsifiable oils may contain fat, soap or various other additives.

4. Vegetable and Animal Fats and Oils - These originate primarily from processing of foods and natural products.

These compounds can settle or float and may exist as solids or liquids depending upon factors such as method of use, production process, and temperature of wastewater.

Even small quantities of oils and grease cause troublesome taste and odor problems. Scum lines from these agents are produced on water treatment basin walls and other containers. Fish and water fowl are adversely affected by oils in their habitat. Oil emulsions may adhere to the gills of fish, causing suffocation, and the flesh of fish is tainted when microorganisms that were exposed to waste oil are eaten. Deposition of oil in the bottom sediments of water can serve to inhibit normal benthic growth. Oil and grease exhibit an oxygen demand.

Many of the organic priority pollutants will be found distributed between the oily phase and the aqueous phase in industrial wastewaters. The presence of phenols, PCBs, PAHs, and almost any other organic pollutant in the oil and grease make characterization of this parameter almost impossible. However, all of these other organics add to the objectionable nature of the oil and grease.

Levels of oil and grease which are toxic to aquatic organisms vary greatly, depending on the type and the species susceptibility. However, it has been reported that crude oil in concentrations as low as 0.3 mg/l is extremely toxic to freshwater fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km show up as a sheen on the surface of a body of water. The presence of oil slicks decreases the aesthetic value of a waterway.

Oil and grease is compatible with a POTW activated sludge process in limited quantity. However, slug loadings or high concentrations of oil and grease interfere with biological treatment processes. The oils coat surfaces and solid particles, preventing access of oxygen, and sealing in some microorganisms. Land spreading of POTW sludge containing oil and grease uncontaminated by toxic pollutants is not expected to affect crops grown on the treated land, or animals eating those crops.

pH. Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not, however, a measure of either. The term pH is used to describe the hydrogen ion concentration (or activity) present in a given solution. Values for pH range from 0 to 14, and these numbers are the negative logarithms of the hydrogen ion concentrations. A pH of 7 indicates neutrality. Solutions with a pH above 7 are alkaline, while those solutions with a pH below 7 are acidic.

The relationship of pH and acidity and alkalinity is not necessarily linear or direct. Knowledge of the water pH is useful in determining necessary measures for corrosion control, sanitation, and disinfection. Its value is also necessary in the treatment of industrial wastewaters to determine amounts of chemicals required to remove pollutants and to measure their effectiveness. Removal of pollutants, especially dissolved solids, is affected by the pH of the wastewater.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the taste of the water and at a low pH, water tastes sour. The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7.0. This is significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from acceptable criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. For example, metallocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units.

Because of the universal nature of pH and its effect on water quality and treatment, it is selected as a pollutant parameter for all subcategories in the coil coating industry. A neutral pH range (approximately 6-9) is generally desired because either extreme beyond this range has a deleterious effect on receiving waters or the pollutant nature of other wastewater constituents.

Pretreatment for regulation of pH is covered by the "General Pretreatment Regulations for Existing and New Sources of Pollution," 40 CFR 403.5. This section prohibits the discharge to a POTW of "pollutants which will cause corrosive structural damage to the POTW but in no case discharges with pH lower than 5.0 unless the works is specially designed to accommodate such discharges."

Total Suspended Solids(TSS). Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly, and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, suspended solids increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Supended solids in water interfere with many industrial processes and cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in the water. Solids, when transformed to sludge deposit, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. Organic solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Total suspended solids is a traditional pollutant which is compatible with a well-run POTW. With the exception of those components which are described elsewhere in this section, e.g., toxic metal components, this pollutant does not interfere with the operation of a POTW; however, since a considerable portion of the innocuous TSS may be inseparably bound to the constituents which do interfere with POTW operation, or produce unusable sludge, or subsequently dissolve to produce unacceptable POTW effluent, TSS may be considered a toxic waste hazard.

SPECIFIC POLLUTANTS CONSIDERED FOR REGULATION

Discussion of individual pollutant parameters selected or not selected for consideration for specific regulation is based on concentrations obtained from sampling and analysis of raw wastewater streams.

Canmaking

Pollutant Parameters Considered for Specific Regulation. Based on sampling results and a careful examination of the canmaking subcategory manufacturing processes and raw materials, 16 pollutant parameters were selected for consideration for specific regulation in effluent limitations and standards for this subcategory. The 16 are: 1,1,1-trichloroethane, 1,1-dichloroethylene, methylene chloride, bis(2-ethylhexy) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, toluene, chromium (total), zinc, aluminum, fluoride, phenols (total), phosphorus, oil and grease, pH, and total suspended solids. These pollutant parameters were found at treatable levels in raw wastewater from processes in this subcategory and are amenable to control by identified wastewater treatment practices.

The seven organic compounds listed above were found at maximum concentrations ranging from 0.022 mg/l to 4.10 mg/l. A total of 25 quantifiable concentrations was found out of a total of 63 analyzed samples. Toxic organics are found in some of the oils used on coil stock supplied to canmakers. The concentrations reported can be reduced with specific treatment methods. Therefore, total toxic organics are considered for regulation in the subcategory.

Chromium was detected in 15 of 15 samples of raw wastewater from this subcategory. The maximum concentration was 5.41 mg/l. Chromium compounds are used in surface treatment formulations in some canwashers. More then one-third of the concentration are greater than those that can be achieved with specific treatment methods. Therefore, chromium is considered for specific regulation in this subcategory.

Zinc was detected in 15 of 15 samples of raw wastewater from this subcategory. The maximum concentration was 4.647 mg/l. Zinc is an alloying element in aluminum coil stock used for canmaking. Some of the zinc concentrations are greater than those that can be achieved with specific treatment methods. Therefore, zinc is considered for specific regulation in this subcategory.

Aluminum was detected in all nine of the samples of raw wastewater analyzed. The maximum concentration was 370 mg/l. Aluminum is the primary constituent of aluminum can coil stock. All nine of the concentrations are greater than those that can be achieved with specific treatment methods. Therefore, aluminum is considered for specific regulation in this subcategory.

Fluoride was detected in all six samples of raw wastewater analyzed. The maximum concentration was 18.02 mg/l. Fluoride ions result from the hydrofluoric acid used in the acid cleaning stage of the canwasher and sometimes in surface treating compositions. The average of all six fluoride concentrations is greater than the long-term average that can be achieved with specific treatment methods. In addition, because of the almost universal use of this material in canmakers and the human health effects of concentrations well below the treatable levels fluoride is considered for specific regulation in this subcategory.

Phosphorus was detected in all six samples of raw wastewater analyzed. The maximum concentration was 12.90 mg/l. Phosphates are used in some surface treatment compositions. The average of all six phosphorus concentration is greater than the long-term average that can be achieved with specific treatment methods. In addition, because phosphates are used in many canwashers phosphorus is considered for specific regulation in this subcategory.

Oil and grease was detected in all 15 of the raw wastewater samples analyzed. The maximum concentration was 45,094 mg/l. Oils are used for lubrication and cooling of the can stock in all seamless canmaking lines. All concentrations are greater than those that can be achieved with specific treatment methods. Therefore, oil and grease is considered for specific regulation in this subcategory.

pH ranged from 1.8 to 6.2 for the six raw wastewater samples measured. pH can be controlled within the range 7.5 to 10 with specific treatment methods and is therefore considered for specific regulation in this subcategory.

Total suspend solids was present in all 15 raw wastewater samples analyzed. The maximum concentration was 3309 mg/l. Suspended solids result from various forming and cleaning operations during canmaking. All the concentrations are greater than those that can be achieved with specific treatment methods. Therefore, total suspended solids is considered for specific regulation in this subcategory.

Pollutant Parameters Not Considered for Specific Regulation. A total of eight pollutant parameters that were evaluated in sampling and analysis were dropped from further consideration from specific regulation in the canmaking subcategory. These parameters were found to be present in raw wastewater from small, unique sources or at levels below those usually achieved by specific treatment methods. The eight are: bis(2-chloroethyl) ether, arsenic, cadmium, copper, cyanide, lead, mercury, and nickel.

Bis(2-chlorethyl) ether was found at a quantifiable level in only one sample of nine on which analyzes were performed. The concentration was 0.0103 mg/l just above the quantification level. Therefore,bis(2-chloroethyl) ether is not considered for specific regulation in this subcategory.

Arsenic was detected in six of the fifteen raw wastewater samples analyzed. The maximum concentration was 1.402 mg/l. This was the only concentration above the levels which are considered treatable by specific methods. Therefore, arsenic is not considered for specific regulation in this subcategory.

Cadmium was detected in six of the fifteen raw wastewater samples analyzed. The maximum concentration was 0.010 mg/l which is below the level considered treatable. Therefore, cadmium is not considered for specific regulation in this subcategory.

Copper was detected in all fifteen raw wastewater samples analyzed. The maximum concentration was 0.09 mg/l which is below the level considered treatable. Therefore, copper is not considered for specific regulation in this subcategory.

Cyanide was detected in eleven of the fifteen raw wastewater samples analyzed. The maximum concentration was 0.034 mg/l which is below the level which is considered treated by specific methods. Therefore, cyanide is not considered for specific regulation in this subcategory.

Lead was detected in seven of the fifteen raw wastewater samples analyzed. The maximum concentration was 0.052 mg/l which is below the levels considered treatable by specific methods. Therefore, lead is not considered for specific regulation in this subcategory.

Mercury was detected in seven of the fifteen raw wastewater samples analyzed. The maximum concentration was 0.001 mg/l which is below the levels considered treatable by specific methods. Therefore, mercury is not considered for regulation in this subcategory.

Nickel was detected in eight of the fifteen raw wastewater samples analyzed. The maximum concentration was 0.49 mg/l which is below the levels considered treatable. Therefore, nickel is not considered for specific regulation in this subcategory.

Summary

Table VI-1, (page 98) presents the results of selection of priority pollutant parameters for consideration for specific regulation for the canmaking subcategory. The pollutants that were not detected are indicated by ND; those detected, but not quantifiable by NQ; those detected at small levels or from a unique source by SU; those at levels considered not treatable by NT; and those considered for specific regulation by REG.

TABLE VI-1

PRIORITY POLLUTANT DISPOSITION

Pollutant	Disposition
1. Acenaphthene	ND
2. Acrolein	ND
3. Acrylonitrile	ND
4. Benzene	NQ
5. Benzidene	ND
6. Carbon tetrachloride	NQ
7. Chlorobenzene	NQ
8. 1,2,4-Trichlorobenzene	ND
9. Hexachlorobenzene	ND
10. 1,2-Dichloroethane	ND
11. 1,1,1-Trichloroethane	REG
12. Hexachloroethane	ND
13. 1,1-Dichloroethane	ND
14. 1,7,2-Trichloroethane	ND
15. 1,1,2,2-Tetrachloroethane	ND
16. Chloroethane	ND
17. Bis(chloromethyl)ether	ND
18. Bis(2-Chloroethyl)ether	SU
19. 2-Chloroethyl vinyl ether	ND
20. 2-Chloronaphthalene	ND
21. 2,4,6-Trichlorophenol	ND
22. Parachlorometa cresol	ND
23. Chloroform	NQ
24. 2-Chlorophenol	ND
25. 1,2-Dichlorobenzene	ND
26. 1,3-Dichlorobenzene	ND
27. 1,4-Dichlorobenzene	ND
28. 3,3-Dichlorobenzidene	ND
29. 1,1-Dichloroethylene	REG
30. 1,2-Trans-Dichloroethylene	ND
31. 2,4-Dichlorophenol	ND
32. 1,2-Dichloropropane	ND
33. 1,2-Dichloropropylene	ND
34. 2,3-Dimethylphenol	ND
35. 2,4-Dinitrotoluene	ND
36. 2,6-Dinitrotoluene	ND
37. 1,2-Diphenylhydrazine	NQ
38. Ethylbenzene	NQ
39. Fluoranthene	ND
40. 4-Chlorophenyl phenyl ether	ND
41. 4-Bromophenyl phenyl ether	ND
42. Bis(2-Chloroisopropyl)ether	ND
43. Bis(2-Chloroethoxy)methane	ND
44. Methylene chloride	REG
45. Methyl chloride	ND
46. Methyl bromide	ND
47. Bromoform	ND
48. Dichlorobromomethane	NQ
49. Trichlorofluoromethane	ND
50. Dichlorodifluoromethane	ND
51. Chlorodibromomethane	NQ
52. Hexachlorobutadiene	ND
53. Hexachlorocyclopentadiene	ND
54. Isophorone	ND
55. Naphthalene	NQ
56. Nitrobenzene	ND
57. 2-Nitrophenol	ND
58. 4-Nitrophenol	ND
59. 2,4-Dinitrophenol	ND
60. 4,6-Dinitro-o-cresol	ND
61. N-Nitrosodimethylamine	ND

ND - NOT DETECTED
NQ - NOT QUANTIFIABLE
SU - SMALL, UNIQUE SOURCE
NT - NOT TREATABLE
REG - REGULATION CONSIDERED

TABLE VI-1 (Continued)

PRIORITY POLLUTANT DISPOSITION

Pollutant	Disposition	Pollutant	Disposition
62. N-Nitrosodiphenylamine	NQ	97. Endosulfan Sulfate	NQ
63. N-Nitrosodi-n-propylamine	ND	98. Endrin	NQ
64. Pentachlorophenol	ND	99. Endrin aldehyde	ND
65. Phenol	NQ	100. Heptachlor	NQ
66. Bis(2-ethylhexyl)phthalate	REG	101. Heptachlor epoxide	NQ
67. Butyl benzyl phthalate	REG	102. Alpha-BHC	NQ
68. Di-n-butyl phthalate	REG	103. Beta-BHC	NQ
69. Di-n-octyl phthalate	ND	104. Gamma-BHC	NQ
70. Diethyl phthalate	NQ	105. Delta-BHC	ND
71. Dimethyl phthalate	NQ	106. PCB-1242	ND
72. 1,2-Benzathracene	NQ	107. PCB-1254	NQ
73. Benzo(a)pyrene	ND	108. PCB-1221	ND
74. 3,4-Benzofluoranthene	ND	109. PCB-1332	ND
75. 11,12-Benzofluoranthene	ND	110. PCB-1248	NQ
76. Chrysene	NQ	111. PCB-1260	ND
77. Acenaphthylene	ND	112. PCB-1016	ND
78. Anthracene	NQ	113. Toxaphene	ND
79. 1,2-Benzoperylene	ND	114. Antimony	ND
80. Fluorene	NQ	115. Arsenic	NT
81. Phenanthrene	NQ	116. Asbestos	ND
82. 1,2,5,6-Dibenzanthracene	ND	117. Beryllium	ND
83. Indeno(1,2,3-Cd)pyrene	ND	118. Cadmium	NT
84. Pyrene	ND	119. Chromium	REG
85. Tetrachloroethylene	NQ	120. Copper	NT
86. Toluene	REG	121. Cyanide	NT
87. Trichloroethylene	NQ	122. Lead	NT
88. Vinyl chloride	ND	123. Mercury	NT
89. Aldrin	ND	124. Nickel	NT
90. Dieldrin	ND	125. Selenium	ND
91. Chlordane	NQ	126. Silver	ND
92. 4,4-DDT	NQ	127. Thallium	ND
93. 4,4-DDE	NQ	128. Zinc	REG
94. 4,4-DDD	ND	129. 2,3,4,8-tetrachloro-dibenzo-P-dioxin(TCDD)	ND
95. Alpha-endosulfan	ND		
96. Beta-endosulfan	ND		

ND - NOT DETECTED
NQ - NOT QUANTIFIABLE
SU - SMALL, UNIQUE SOURCE
NT - NOT TREATABLE
REG - REGULATION CONSIDERED

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the treatment techniques currently used or available to remove or recover wastewater pollutants normally generated by the canmaking subcategory of the coil coating industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies. These treatment technologies are widely used in many industrial categories and data and information to support their effectiveness have been drawn from a similarly wide range of sources and data bases.

END-OF-PIPE TREATMENT TECHNOLOGIES

Individual recovery and treatment technologies are described which are used or are suitable for use in treating wastewater discharges from canmaking facilities. Each description includes a functional description and discussions of application and performance, advantages and limitations, operational factors (reliability, maintainability, solid waste aspects), and demonstration status. The treatment processes described include both technologies presently demonstrated within the canmaking subcategory and technologies demonstrated in treatment of similar wastes in other industries.

Canmaking wastewater streams characteristically contain significant levels of the toxic metals chromium and zinc plus toxic organic pollutants which are associated with high levels of oil and grease generated during the drawing and ironing process. Additionally, the conventional pollutant parameters TSS and pH, are found as are the nonconventional pollutants aluminum, fluoride and phosphorus.

In general, these pollutants are removed by chemical precipitation and sedimentation or filtration. Most of them may be effectively removed by precipitation of metal hydroxides or carbonates utilizing the reaction with lime, sodium hydroxide, or sodium carbonate. For some, improved removals are provided by the use of sodium sulfide or ferrous sulfide to precipitate the pollutants as sulfide compounds with very low solubilities. Preliminary treatment may also be necessary including chromium reduction, cyanide destruction, emulsion breaking and dissolved air flotation.

Discussion of end-of-pipe treatment technologies is divided into three parts: the major technologies; the effectiveness of major technologies; and minor end-of-pipe technologies.

MAJOR TECHNOLOGIES

In Sections IX, X, XI and XII, the rationale for selecting treatment systems is discussed. The individual technologies used in the system are described here. The major end-of-pipe technologies are: chemical reduction of hexavalent chromium, chemical precipitation of dissolved metals, cyanide precipitation, granular bed filtration, pressure filtration, settling of suspended solids, chemical emulsion breaking, dissolved air flotation, and skimming of oil. In practice, precipitation of metals and settling of the resulting precipitates is often a unified two-step operation. Suspended solids originally present in raw wastewaters are not appreciably affected by the precipitation operation and are removed with the precipitated metals in the settling operations. Settling operations can be evaluated independently of hydroxide or other chemical precipitation operations, but hydroxide and other chemical precipitation operations can only be evaluated in combination with a solids removal operation.

1. Chemical Reduction Of Chromium

Description of the Process. Reduction is a chemical reaction in which electrons are transferred to the chemical being reduced from the chemical initiating the transfer (the reducing agent). Sulfur dioxide, sodium bisulfite, sodium metabisulfite, and ferrous sulfate form strong reducing agents in aqueous solution and are often used in industrial waste treatment facilities for the reduction of hexavalent chromium to the trivalent form. The reduction allows removal of chromium from solution in conjunction with other metallic salts by alkaline precipitation. Hexavalent chromium is not precipitated as the hydroxide.

Gaseous sulfur dioxide is a widely used reducing agent and provides a good example of the chemical reduction process. Reduction using other reagents is chemically similar. The reactions involved may be illustrated as follows:

$$3\ SO_2 + 3\ H_2O \text{---------->} 3\ H_2SO_3$$

$$3\ H_2SO_3 + 2H_2CrO_4 \text{--->} Cr_2(SO_4)_3 + 5\ H_2O$$

The above reaction is favored by low pH. A pH of from 2 to 3 is normal for situations requiring complete reduction. At pH levels above 5, the reduction rate is slow. Oxidizing agents such as dissolved oxygen and ferric iron interfere with the reduction process by consuming the reducing agent.

A typical treatment consists of 45 minutes retention in a reaction tank. The reaction tank has an electronic recorder-controller device to control process conditions with respect to pH and oxidation reduction potential (ORP). Gaseous sulfur dioxide is metered to the reaction tank to maintain the ORP within the range of 250 to 300 millivolts. Sulfuric acid is added to maintain a pH level of from 1.8 to 2.0. The reaction tank is equipped with a propeller agitator designed to provide approximately one turnover per minute. Figure VII-13 (page 206) shows a continuous chromium reduction system.

Application and Performance. It may be necessary in the canmaking subcategory to treat wastewater from cans which have been surface treated with a chromium conversion coating. A study of an operational wastewater treatment facility chemically reducing hexavalent chromium has shown that a 99.7 percent reduction efficiency is easily achieved. Final concentrations of 0.05 mg/l are readily attained, and concentrations of 0.01 mg/l are considered to be attainable by properly maintained and operated equipment.

Advantages and Limitations. The major advantage of chemical reduction to reduce hexavalent chromium is that it is a fully proven technology based on many years of experience. Operation at ambient conditions results in low energy consumption, and the process, especially when using sulfur dioxide, is well suited to automatic control. Furthermore, the equipment is readily obtainable from many suppliers, and operation is straightforward.

One limitation of chemical reduction of hexavalent chromium is that for high concentrations of chromium, the cost of treatment chemicals may be prohibitive. When this situation occurs, other treatment techniques are likely to be more economical. Chemical interference by oxidizing agents is possible in the treatment of mixed wastes, and the treatment itself may introduce pollutants if not properly controlled. Storage and handling of sulfur dioxide is somewhat hazardous.

Operational Factors. Reliability: Maintenance consists of periodic removal of sludge. The frequency of removal is a function of the input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may often be necessary. The reduction process produces trivalent chromium which can be controlled by further treatment. There may, however, be small amounts of sludge collected due to minor shifts in the solubility of the contaminants. This sludge can be processed by the main sludge treatment equipment.

Demonstration Status. The reduction of chromium waste by sulfur dioxide or sodium bisulfite is a classic process and is used by numerous plants which have hexavalent chromium compounds in wastewaters from operations such as electroplating, conversion coating, and noncontact cooling. Seven canmaking plants reported practicing chromium reduction.

2. Chemical Precipitation

Dissolved toxic metal ions and certain anions may be chemically precipitated for subsequent removal by physical means such as sedimentation, filtration, or centrifugation. Several reagents are commonly used to effect this precipitation.

1) Alkaline compounds such as lime or sodium hydroxide may be used to precipitate many toxic metal ions as metal hydroxides. Lime also may precipitate phosphates as insoluble calcium phosphate and fluorides as calcium fluoride.

2) Both "soluble" sulfides such as hydrogen sulfide or sodium sulfide and "insoluble" sulfides such as ferrous sulfide may be used to precipitate many heavy metal ions as insoluble metal sulfides.

3) Ferrous sulfate, zinc sulfate or both (as is required) may be used to precipitate cyanide as a ferro or zinc ferricyanide complex.

4) Carbonate precipitates may be used to remove metals either by direct precipitation using a carbonate reagent such as calcium carbonate or by converting hydroxides into carbonates using carbon dioxide.

These treatment chemicals may be added to a flash mixer or rapid mix tank, to a presettling tank, or directly to a clarifier or other settling device. Because metal hydroxides tend to be colloidal in nature, coagulating agents may also be added to facilitate settling. After the solids have been removed, final pH adjustment may be required to reduce the high pH created by the alkaline treatment chemicals.

Chemical precipitation as a mechanism for removing metals from wastewater is a complex process of at least two steps - precipitation of the unwanted metals and removal of the precipitate. Some small amount of metal will remain dissolved in the wastewater after precipitation is complete. The amount of residual dissolved metal depends on the treatment chemicals used and related factors. The effectiveness of this method of removing any specific metal depends on the fraction of the specific metal in the raw wastewater (and hence in the precipitate) and the effectiveness of suspended solids removal. In specific instances, a sacrifical ion such as iron or aluminum may be added to aid in the precipitation process and reduce the fraction of a specific metal in the precipitate.

Application and Performance. Chemical precipitation is used in canmaking for precipitation of dissolved metals. It can be used to remove metal ions such as aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, tin and zinc. The process is also applicable to any substance that can be transformed into an insoluble form such as fluorides, phosphates, soaps, sulfides and others. Because it is simple and effective, chemical precipitation is extensively used for industrial wastewater treatment.

The performance of chemical precipitation depends on several variables. The most important factors affecting precipitation effectiveness are:

1. Maintenance of an alkaline pH throughout the precipitation reaction and subsequent settling;

2. Addition of a sufficient excess of treatment ions to drive the precipitation reaction to completion;

3. Addition of an adequate supply of sacrifical ions (such as iron or aluminum) to ensure precipitation and removal of specific target ions; and

4. Effective removal of precipitated solids (see appropriate technologies discussed under "Solids Removal").

Control of pH. Irrespective of the solids removal technology employed, proper control of pH is absolutely essential for favorable performance of precipitation-sedimentation technologies. This is clearly illustrated by solubility curves for selected metal hydroxides and sulfides shown in Figure VII-1 (page 194), for lead in three alkalies in Figure VII-2 (page 195), and by plotting effluent zinc concentrations against pH as shown in Figure VII-3 (page 196). Figure VII-3 was obtained from Development Document for the Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Zinc Segment of Nonferrous Metals Manufacturing Point Source Category, U.S. E.P.A., EPA 440/1-74/033, November, 1974. Figure VII-3 was plotted from the sampling data from several facilities with metal finishing operations. It is partially illustrated by data obtained from 3 consecutive days of sampling at one metal processing plant as displayed in Table VII-1 (page 174). Flow through this system is approximately 49,263 l/hr (13,000 gal/hr).

This treatment system uses lime precipitation (pH adjustment) followed by coagulant addition and sedimentation. Samples were taken before (in) and after (out) the treatment system. The best treatment for removal of copper and zinc was achieved on day one, when the pH was maintained at a satisfactory level. The poorest treatment was found on the second day, when the pH slipped to an unacceptably low level, and intermediate values were achieved on the third day when pH values were less than desirable but in between those of the first and second days.

Sulfide Precipitation is sometimes used to precipitate metals resulting in improved metals removals. Most metal sulfides are less soluble than hydroxides and the precipitates are frequently more dependably removed from water. Solubilities for selected metal hydroxide, carbonate and sulfide precipitates are shown in Table VII-4 (page 175) (Source: Lange's *Handbook of Chemistry*). Sulfide precipitation is particularly effective in removing specific metals such as silver and mercury. Sampling data from three industrial plants using sulfide precipitation appear in Table VII-5 (page 176).

In all cases except iron, effluent concentrations are below 0.1 mg/l and in many cases below 0.01 mg/l for the three plants studied.

Sampling data from several chlorine-caustic manufacturing plants using sulfide precipitation demonstrate effluent mercury concentrations varying between 0.009 and 0.03 mg/l. As shown in Figure VII-1, the solubilities of PbS and Ag_2S are lower at alkaline pH levels than either the corresponding hydroxides or other sulfide compounds. This implies that removal performance for lead and silver sulfides should be comparable to or better than that for the heavy metal hydroxides. Bench scale tests on several types of metal finishing and manufacturing wastewater indicate that metals removal to levels of less than 0.05 mg/l and in some cases less than 0.01 mg/l are common in systems using sulfide precipitation followed by clarification. Some of the bench scale data, particularly in the case of lead, do not support such low effluent concentrations. However, lead is consistently removed to very low levels (less than 0.02 mg/l) in systems using hydroxide and carbonate precipitation and sedimentation.

Of particular interest is the ability of sulfide to precipitate hexavalent chromium (Cr^{+6}) without prior reduction to the trivalent state as is required in the hydroxide process. When ferrous sulfide is used as the precipitant, iron and sulfide act as reducing agents for the hexavalent chromium according to the reaction:

$$CrO_3 + FeS + 3H_2O \text{ ----> } Fe(OH)_3 + Cr(OH)_3 + S$$

The sludge produced in this reaction consists mainly of ferric hydroxides, chromic hydroxides and various metallic sulfides. Some excess hydroxyl ions are generated in this process, possibly requiring a downward re-adjustment of pH.

Based on the available data, Table VII-6 (page 177) shows the minimum reliably attainable effluent concentrations for sulfide precipitation-sedimentation systems. These values are used to calculate performance predictions of sulfide precipitation-sedimentation systems.

Carbonate Precipitation is sometimes used to precipitate metals, especially where precipitated metals values are to be recovered. The solubility of most metal carbonates is intermediate between hydroxide and sulfide solubilities; in addition, carbonates form easily filtered precipitates.

Carbonate ions appear to be particularly useful in precipitating lead and antimony. Sodium carbonate has been observed being added at treatment to improve lead precipitation and removal in some industrial plants. The lead hydroxide and lead carbonate solubility curves displayed in Figure VII-2 (page 195) ("Heavy Metals Removal," by Kenneth Lanovette, Chemical Engineering/Deskbook Issue, Oct. 17, 1977) explain this phenomenon.

Co-precipitation With Iron- The presence of substantial quantities of iron in metal bearing wastewaters before treatment has been shown to improve the removal of toxic metals. In some cases this iron is an integral part of the industrial wastewater; in other cases iron is deliberately added as a pre or first step of treatment. The iron functions to improve toxic metal removal by three mechanisms: the iron co-precipitates with toxic metals forming a stable precipitate which desolubilizes the toxic metal; the iron improves the settleability of the precipitate; and the large amount of iron reduces the fraction of toxic metal in the precipitate. Co-precipitation with iron has been practiced for many years-incidentally when iron was a substantial consitutent of raw wastewater and intentionally when iron salts were added as a coagulant aid. Aluminum or mixed iron-aluminum salt also have been used.

Co-precipitation using large amounts of ferrous iron salts is known as ferrite co-precipitation because magnetic iron oxide or ferrite is formed. The addition of ferrous salts (sulfate) is followed by alkali precipitation and air oxidation. The resultant precipitate is easily removed by filtration and may be removed magnetically. Data illustrating the performance of ferrite co-precipitation is shown in Table VII-7 (page 178).

Advantages and Limitations

Chemical precipitation has proven to be an effective technique for removing many pollutants from industrial wastewater. It operates at ambient conditions and is well suited to automatic control. The use of chemical precipitation may be limited because of interference by chelating agents, because of possible chemical interference of mixed wastewaters and treatment chemicals, or because of the potentially hazardous situation involved with the storage and handling of those chemicals. Lime is usually added as a slurry when used in hydroxide precipitation. The slurry must be kept well mixed and the addition lines periodically checked to prevent blocking of the lines, which may result from a buildup of solids. Also, hydroxide precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most hydroxide sludges.

The major advantage of the sulfide precipitation process is that the extremely low solubility of most metal sulfides promotes very high metal removal efficiencies; the sulfide process also has the ability to remove chromates and dichromates without preliminary reduction of the chromium to its trivalent state. In addition, sulfide can precipitate metals complexed with most complexing agents. The process demands care, however, in maintaining the pH of the solution at approximately 10 in order to prevent the generation of toxic hydrogen sulfide gas. For this reason, ventilation of the treatment tanks may be a necessary precaution in most installations. The use of insoluble sulfides reduces the problem of hydrogen sulfide evolution. As with hydroxide precipitation, excess sulfide ion must be present to drive the precipitation reaction to completion. Since the sulfide ion itself is toxic, sulfide addition must be carefully controlled to maximize heavy metals precipitation with a minimum of excess sulfide to avoid the necessity of post treatment. At very high excess sulfide levels and high pH, soluble mercury-sulfide compounds may also be formed. Where excess sulfide is present, aeration of the effluent stream can aid in oxidizing residual sulfide to the less harmful sodium sulfate (Na_2SO_4). The cost of sulfide precipitants is high in comparison with hydroxide precipitants, and disposal of metallic sulfide sludges may pose problems. An essential element in effective sulfide precipitation is the removal of precipitated solids from the wastewater and proper disposal in an appropriate site. Sulfide precipitation will also generate a higher volume of sludge, than hydroxide precipitation, resulting in higher disposal and dewatering costs. This is especially true when ferrous sulfide is used as the precipitant.

Sulfide precipitation may be used as a polishing treatment after hydroxide precipitation-sedimentation. This treatment configuration may provide the better treatment effectiveness of sulfide precipitation while minimizing the variability caused by changes in raw wastewater composition and reducing the amount of sulfide precipitant required.

Operational Factors. Reliability: Alkaline chemical precipitation is highly reliable, although proper monitoring and control are required. Sulfide precipitation systems provide similar reliability.

Maintainability: The major maintenance needs involve periodic upkeep of monitoring equipment, automatic feeding equipment, mixing equipment, and other hardware. Removal of accumulated sludge is necessary for efficient operation of precipitation-sedimentation systems.

Solid Waste Aspects: Solids which precipitate out are removed in a subsequent treatment step. Ultimately, these solids require proper disposal.

Demonstration Status. Chemical precipitation of metal hydroxides is a classic wastewater treatment technology used by most industrial wastewater treatment systems. Chemical precipitation of metals in the carbonate form alone has been found to be feasible and is commercially used to permit metals recovery and water reuse. Full scale commercial sulfide precipitation units are in operation at numerous installations. As noted earlier, sedimentation to remove precipitates is discussed separately.

Use in Canmaking Plants. Chemical precipitation equipment is in place at 57 canmaking plants plants, however only a limited amount of canmaking effluent data were received.

3. Cyanide Precipitation

Cyanide precipitation, although a method for treating cyanide in wastewaters, does not destroy cyanide. The cyanide is retained in the sludge that is formed. Reports indicate that during exposure to sunlight the cyanide complexes can break down and form free cyanide. For this reason the sludge from this treatment method must be disposed of carefully.

Cyanide may be precipitated and settled out of wastewaters by the addition of zinc sulfate or ferrous sulfate. In the presence of iron, cyanide will form extremely stable cyanide complexes. The addition of zinc sulfate or ferrous sulfate forms zinc ferrocyanide or ferro and ferricyanide complexes.

Adequate removal of the precipitated cyanide requires that the pH must be kept at 9.0 and an appropriate retention time be maintained. A study has shown that the formation of the complex is very dependent on pH. At pH's of 8 and 10 the residual cyanide concentrations measured are twice those of the same reaction carried out at a pH of 9. Removal efficiencies also depend heavily on the retention time allowed. The formation of the complexes takes place rather slowly. Depending upon the excess amount of zinc sulfate or ferrous sulfate added, at least a 30 minute retention time should be allowed for the formation of the cyanide complex before continuing on to the clarification stage.

One experiment with an initial concentration of 10 mg/l of cyanide showed that 98 percent of the cyanide was complexed ten minutes after the addition of ferrous sulfate at twice the theoretical amount necessary. Interference from other metal ions, such as cadmium, might result in the need for longer retention times.

Table VII-8 (page 178) presents cyanide precipitation data from three coil coating plants.

Plant 1057 allowed a 27 minute retention time for the formation of the complex. The retention time for the other plants is not known. The data suggest that over a wide range of cyanide concentration in the raw wastewater, the concentration of cyanide can be reduced in the effluent stream to under 0.15 mg/l.

Application and Performance. Cyanide precipitation can be used when cyanide destruction is not feasible because of the presence of cyanide complexes which are difficult to destroy. Effluent concentrations of cyanide well below 0.15 mg/l are possible.

Advantages and Limitations. Cyanide precipitation is an inexpensive method of treating cyanide. Problems may occur when metal ions interfere with the formation of the complexes.

Demonstration Status: Cyanide precipitation is used in at least six coil coating plants but is not reported to be used at any canmaking plants.

4. Granular Bed Filtration

Filtration occurs in nature as the surface ground waters are cleansed by sand. Silica sand, anthracite coal, and garnet are common filter media used in water treatment plants. These are usually supported by gravel. The media may be used singly or in combination. The multi-media filters may be arranged to maintain relatively distinct layers by virtue of balancing the forces of gravity, flow, and buoyancy on the individual particles. This is accomplished by selecting appropriate filter flow rates (gpm/sq-ft), media grain size, and density.

Granular bed filters may be classified in terms of filtration rate, filter media, flow pattern, or method of pressurization. Traditional rate classifications are slow sand, rapid sand, and high rate mixed media. In the slow sand filter, flux or hydraulic loading is relatively low, and removal of collected solids to clean the filter is therefore relatively infrequent. The filter is often cleaned by scraping off the inlet face (top) of the sand bed. In the higher rate filters, cleaning is frequent and is accomplished by a periodic backwash, opposite to the direction of normal flow.

A filter may use a single medium such as sand or diatomaceous earth, but dual and mixed (multiple) media filters allow higher flow rates and efficiencies. The dual media filter usually consists of a fine bed of sand under a coarser bed of anthracite coal. The coarse coal removes most of the influent solids, while the fine sand performs a polishing function. At the end of the backwash, the fine sand settles to the bottom because it is denser than the coal, and the filter is ready for normal operation. The mixed media filter operates on the same principle, with the finer, denser media at the bottom and the coarser, less dense media at the top. The usual arrangement is garnet at the bottom (outlet end) of the bed, sand in the middle, and anthracite coal at the top. Some mixing of these layers occurs and is, in fact, desirable.

The flow pattern is usually top-to-bottom, but other patterns are sometimes used. Upflow filters are sometimes used, and in a horizontal filter the flow is horizontal. In a biflow filter, the influent enters both the top and the bottom and exits laterally. The advantage of an upflow filter is that with an upflow backwash the particles of a single filter medium are distributed and maintained in the desired coarse-to-fine (bottom-to-top) arrangement. The disadvantage is that the bed tends to become fluidized, which ruins filtration efficiency. The biflow design is an attempt to overcome this problem.

The classic granular bed filter operates by gravity flow; however, pressure filters are fairly widely used. They permit higher solids loadings before cleaning and are advantageous when the filter effluent must be pressurized for further downstream treatment. In addition, pressure filter systems are often less costly for low to moderate flow rates.

Figure VII-14 (page 207) depicts a high rate, dual media, gravity downflow granular bed filter, with self-stored backwash. Both filtrate and backwash are piped around the bed in an arrangement that permits gravity upflow of the backwash, with the stored filtrate serving as backwash. Addition of the indicated coagulant and polyelectrolyte usually results in a substantial improvement in filter performance.

Auxiliary filter cleaning is sometimes employed in the upper few inches of filter beds. This is conventionally referred to as surface wash and is accomplished by water jets just below the surface of the expanded bed during the backwash cycle. These jets enhance the scouring action in the bed by increasing the agitation.

An important feature for successful filtration and backwashing is the underdrain. This is the support structure for the bed. The underdrain provides an area for collection of the filtered water without clogging from either the filtered solids or the media grains. In addition, the underdrain prevents loss of the media with the water, and during the backwash cycle it provides even flow distribution over the bed. Failure to dissipate the velocity head during the filter or backwash cycle will result in bed upset and the need for major repairs.

Several standard approaches are employed for filter underdrains. The simplest one consists of a parallel porous pipe imbedded under a layer of coarse gravel and manifolded to a header pipe for effluent removal. Other approaches to the underdrain system are known as the Leopold and Wheeler filter bottoms. Both of these incorporate false concrete bottoms with specific porosity configurations to provide drainage and velocity head dissipation.

Filter system operation may be manual or automatic. The filter backwash cycle may be on a timed basis, a pressure drop basis with a terminal value which triggers backwash, or a solids carry-over basis from turbidity monitoring of the outlet stream. All of these schemes have been used successfully.

Application and Performance. Wastewater treatment plants often use granular bed filters for polishing after clarification, sedimentation, or other similar operations. Granular bed filtration thus has potential application to nearly all industrial plants. Chemical additives which enhance the upstream treatment equipment may or may not be compatible with or enhance the filtration process. Normal operating flow rates for various types of filters are as follows:

Slow Sand	2.04 - 5.30 l/sq m-hr
Rapid Sand	40.74 - 51.48 l/sq m-hr
High Rate Mixed Media	81.48 - 122.22 l/sq m-hr

Suspended solids are commonly removed from wastewater streams by filtering through a deep 0.3-0.9 m (1-3 feet) granular filter bed. The porous bed formed by the granular media can be designed to remove practically all suspended particles. Even colloidal suspensions (roughly 1 to 100 microns) are adsorbed on the surface of the media grains as they pass in close proximity in the narrow bed passages.

Properly operated filters following some pretreatment to reduce suspended solids below 200 mg/l should produce water with less than 10 mg/l TSS. For example, multimedia filters produced the effluent qualities shown in Table VII-9 (page 179).

The principal advantages of granular bed filtration are its comparatively (to other filters) low initial and operating costs, reduced land requirements over other methods to achieve the same level of solids removal, and elimination of chemical additions to the discharge stream. However, the filter may require pretreatment if the solids level is high (over 100 mg/l). Operator training must be somewhat extensive due to the controls and periodic backwashing involved, and backwash must be stored and dewatered for economical disposal.

Operational Factors. Reliability: The recent improvements in filter technology have significantly improved filtration reliability. Control systems, improved designs, and good operating procedures have made filtration a highly reliable method of water treatment.

Maintainability: Deep bed filters may be operated with either manual or automatic backwash. In either case, they must be periodically inspected for media attrition, partial plugging, and leakage. Where backwashing is not used, collected solids must be removed by shoveling, and filter media must be at least partially replaced.

Solid Waste Aspects: Filter backwash is generally recycled within the wastewater treatment system, so that the solids ultimately appear in the clarifier sludge stream for subsequent dewatering. Alternatively, the backwash stream may be dewatered directly or, if there is no backwash, the collected solids may be disposed of in a suitable landfill. In either of these situations there is a solids disposal problem similar to that of clarifiers.

Demonstration Status. Deep bed filters are in common use in municipal treatment plants. Their use in polishing industrial clarifier effluent is increasing, and the technology is proven and conventional. Granular bed filtration is used in many manufacturing plants. As noted previously, however, little data is available characterizing the effectiveness of filters presently in use within the industry. However, 10 canmaking plants have filtration equipment in-place.

5. Pressure Filtration

Pressure filtration works by pumping the liquid through a filter material which is impenetrable to the solid phase. The positive pressure exerted by the feed pumps or other mechanical means provides the pressure differential which is the principal driving force. Figure VII-15 (page 208) represents the operation of one type of pressure filter.

A typical pressure filtration unit consists of a number of plates or trays which are held rigidly in a frame to ensure alignment and which are pressed together between a fixed end and a traveling end. On the surface of each plate is mounted a filter made of cloth or a synthetic fiber. The feed stream is pumped into the unit and passes through holes in the trays along the length of the press until the cavities or chambers between the trays are completely filled. The solids are then entrapped, and a cake begins to form on the surface of the filter material. The water passes through the fibers, and the solids are retained.

At the bottom of the trays are drainage ports. The filtrate is collected and discharged to a common drain. As the filter medium becomes coated with sludge, the flow of filtrate through the filter drops sharply, indicating that the capacity of the filter has been exhausted. The unit must then be cleaned of the sludge. After the cleaning or replacement of the filter media, the unit is again ready for operation.

Application and Performance. Pressure filtration is used in coil coating for sludge dewatering and also for direct removal of precipitated and other suspended solids from wastewater. Because dewatering is such a common operation in treatment systems, pressure filtration is a technique which can be found in many industries concerned with removing solids from their waste stream.

In a typical pressure filter, chemically preconditioned sludge detained in the unit for one to three hours under pressures varying from 5 to 13 atmospheres exhibited final solids content between 25 and 50 percent.

Advantages and Limitations. The pressures which may be applied to a sludge for removal of water by filter presses that are currently available range from 5 to 13 atmospheres. As a result, pressure filtration may reduce the amount of chemical pretreatment required for sludge dewatering. Sludge retained in the form of the filter cake has a higher percentage of solids than that from centrifuge or vacuum filter. Thus, it can be easily accommodated by materials handling systems.

As a primary solids removal technique, pressure filtration requires less space than clarification and is well suited to streams with high solids loadings. The sludge produced may be disposed without further dewatering, but the amount of sludge is increased by the use of filter precoat materials (usually diatomaceous earth). Also, cloth pressure filters often do not achieve as high a degree of effluent clarification as clarifiers or granular media filters.

Two disadvantages associated with pressure filtration in the past have been the short life of the filter cloths and lack of automation. New synthetic fibers have largely offset the first of these problems. Also, units with automatic feeding and pressing cycles are now available.

For larger operations, the relatively high space requirements, as compared to those of a centrifuge, could be prohibitive in some situations.

Operational Factors. Reliability: With proper pretreatment, design, and control, pressure filtration is a highly dependable system.

Maintainability: Maintenance consists of periodic cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the system. If the removal of the sludge cake is not automated, additional time is required for this operation.

Solid Waste Aspects: Because it is generally drier than other types of sludges, the filter sludge cake can be handled with relative ease. One of several accepted procedures may be used to dispose of the accumulated sludge, depending on its chemical composition. The levels of toxic metals present in sludge from treating canmaking wastewater necessitate proper disposal.

Demonstration Status. Pressure filtration is a commonly used technology in a great many commercial applications.

6. Settling

Settling is a process which removes solid particles from a liquid matrix by gravitational force. This is done by reducing the velocity of the feed stream in a large volume tank or lagoon so that gravitational settling can occur. Figure VII-16 (page 209) shows two typical settling devices.

Settling is often preceded by chemical precipitation which converts dissolved pollutants to solid form and by coagulation which enhances settling by coagulating suspended precipitates into larger, faster settling particles.

If no chemical pretreatment is used, the wastewater is fed into a tank or lagoon where it loses velocity and the suspended solids are allowed to settle out. Long retention times are generally required. Accumulated sludge can be collected either periodically or continuously and either manually or mechanically. Simple settling, however, may require excessively large catchments, and long retention times (days as compared with hours) to achieve high removal efficiencies. Because of this, addition of settling aids such as alum or polymeric flocculants is often economically attractive.

In practice, chemical precipitation often precedes settling, and inorganic coagulants or polyelectrolytic flocculants are usually added as well. Common coagulants include sodium sulfate, sodium aluminate, ferrous or ferric sulfate, and ferric chloride. Organic polyelectrolytes vary in structure, but all usually form larger floc particles than coagulants used alone.

Following this pretreatment, the wastewater can be fed into a holding tank or lagoon for settling, but is more often piped into a clarifier for the same purpose. A clarifier reduces space requirements, reduces retention time, and increases solids removal efficiency. Conventional clarifiers generally consist of a circular or rectangular tank with a mechanical sludge collecting device or with a sloping funnel-shaped bottom designed for sludge collection. In advanced settling devices inclined plates, slanted tubes, or a lamellar network may be included within the clarifier tank in order to increase the effective settling area, increasing capacity. A fraction of the sludge stream is often recirculated to the inlet, promoting formation of a denser sludge.

Application and Performance. Settling and clarification are used in the canmaking industry to remove precipitated metals. Settling can be used to remove most suspended solids in a particular waste stream; thus it is used extensively by many different industrial wastewater treatment facilities. Because most metal ion pollutants are readily converted to solid metal hydroxide precipitates, settling is of particular use in those industries associated with metal production, metal finishing, metal working, and any other industry with high concentrations of metal ions in their wastewaters. In addition to toxic metals, suitably precipitated materials effectively removed by settling include aluminum, iron, manganese, cobalt, antimony, beryllium, molybdenum, fluoride, phosphate, and many others.

A properly operating settling system can efficiently remove suspended solids, precipitated metal hydroxides, and other impurities from wastewater. The performance of the process depends on a variety of factors, including the density and particle size of the solids, the effective charge on the suspended particles, and the types of chemicals used in pretreatment. The site of flocculant or coagulant addition also may significantly influence the effectiveness of clarification. If the flocculant is subjected to too much mixing before entering the clarifier, the complexes may be sheared and the settling effectiveness diminished. At the same time, the flocculant must have sufficient mixing and reaction time in order for effective set-up and settling to occur. Plant personnel have observed that the line or trough leading into the clarifier is often the most efficient site for flocculant addition. The performance of simple settling is a function of the retention time, particle size and density, and the surface area of the basin.

The data displayed in Table VII-10 (page 179) indicat suspended solids removal efficiencies in settling systems.

The mean effluent TSS concentration obtained by the plants shown in Table VII-10 is 10.1 mg/l. Influent concentrations averaged 838 mg/l. The maximum effluent TSS value reported is 23 mg/l. These plants all use alkaline pH adjustment to precipitate metal hydroxides, and most add a coagulant or flocculant prior to settling.

Advantages and Limitations. The major advantage of simple settling is its simplicity as demonstrated by the gravitational settling of solid particulate waste in a holding tank or lagoon. The major problem with simple settling is the long retention time necessary to achieve complete settling, especially if the specific gravity of the suspended matter is close to that of water. Some materials cannot be practically removed by simple settling alone.

Settling performed in a clarifier is effective in removing slow-settling suspended matter in a shorter time and in less space than a simple settling system. Also, effluent quality is often better from a clarifier. The cost of installing and maintaining a clarifier, however, is substantially greater than the costs associated with simple settling.

Inclined plate, slant tube, and lamella settlers have even higher removal efficiencies than conventional clarifiers, and greater capacities per unit area are possible. Installed costs for these advanced clarification systems are claimed to be one half the cost of conventional systems of similar capacity.

Operational Factors. Reliability: Settling can be a highly reliable technology for removing suspended solids. Sufficient retention time and regular sludge removal are important factors affecting the reliability of all settling systems. Proper control of pH adjustment, chemical precipitation, and coagulant or flocculant addition are additional factors affecting settling efficiencies in systems (frequently clarifiers) where these methods are used.

Those advanced settlers using slanted tubes, inclined plates, or a lamellar network may require pre-screening of the waste in order to eliminate any fibrous materials which could potentially clog the system. Some installations are especially vulnerable to shock loadings, as by storm water runoff, but proper system design will prevent this.

Maintainability: When clarifiers or other advanced settling devices are used, the associated system utilized for chemical pretreatment and sludge dragout must be maintained on a regular basis. Routine maintenance of mechanical parts is also necessary. Lagoons require little maintenance other than periodic sludge removal.

Demonstration Status

Settling represents the typical method of solids removal and is employed extensively in industrial wastewater treatment. The advanced clarifiers are just beginning to appear in significant numbers in commercial applications. Sedimentation or clarification is used in 28 canmaking plants.

7. Skimming

Pollutants with a specific gravity less than water will often float unassisted to the surface of the wastewater. Skimming removes these floating wastes. Skimming normally takes place in a tank designed to allow the floating debris to rise and remain on the surface, while the liquid flows to an outlet located below the floating layer. Skimming devices are therefore suited to the removal of non-emulsified oils from raw waste streams. Common skimming mechanisms include the rotating drum type, which picks up oil from the surface of the water as it rotates. A doctor blade scrapes oil from the drum and collects it in a trough for disposal or reuse. The water portion is allowed to flow under the rotating drum. Occasionally, an underflow baffle is installed after the drum; this has the advantage of retaining any floating oil which escapes the drum skimmer. The belt type skimmer is pulled vertically through the water, collecting oil which is scraped off from the surface and collected in a drum. Gravity separators, such as the API type, utilize overflow and underflow baffles to skim a floating oil layer from the surface of the wastewater. An overflow-underflow baffle allows a small amount of wastewater (the oil portion) to flow over into a trough for disposition or reuse while the majority of the water flows underneath the baffle. This is followed by an overflow baffle, which is set at a height relative to the first baffle such that only the oil bearing portion will flow over the first baffle during normal plant operation. A diffusion device, such as a vertical slot baffle, aids in creating a uniform flow through the system and increasing oil removal efficiency.

Application and Performance. Lubricants cleaned from most seamless cans during the canwashing process are the principal source of oil. Skimming is applicable to any wastewater stream containing pollutants which float to the surface. It is commonly used to remove free oil, grease, and soaps. Skimming is often used in conjunction with air flotation or clarification in order to increase its effectiveness.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

API or other gravity-type separators tend to be more suitable for use where the amount of surface oil flowing through the system is consistently significant. Drum and belt type skimmers are applicable to wastewater streams which evidence smaller amounts of floating oil and where surges of floating oil are not a problem. Using an API separator system in conjunction with a drum type skimmer would be a very effective method of removing floating contaminants from non-emulsified oily waste streams. Sampling data illustrate the capabilities of the technology with both extremely high and moderate oil influent levels.

This data, displayed in Table VII-11 (page 179), is intended to be illustrative of the very high level of oil and grease removals attainable in a simple two stage oil removal system. Based on the performance of installations in a variety of manufacturing plants and permit requirements that are constantly achieved, it is determined that effluent oil levels may be reliably reduced below 10 mg/l with moderate influent concentrations. Very high concentrations of oil such as the 22 percent shown above may require two step treatment to achieve this level.

Skimming which removes oil may also be used to remove base levels of organics. Plant sampling data show that many organic compounds tend to be removed in standard wastewater treatment equipment. Oil separation not only removes oil but also organics that are more soluble in oil than in water. Clarification removes organic solids directly and probably removes dissolved organics by adsorption on inorganic solids.

The source of these organic pollutants is not always known with certainty, although in metal forming operations they seem to derive mainly from various process lubricants. They are also sometimes present in the plant water supply, as additives to proprietary formulations of cleaners, or due to leaching from plastic lines and other materials.

High molecular weight organics in particular are much more soluble in organic solvents than in water. Thus they are much more concentrated in the oil phase that is skimmed than in the wastewater. The ratio of solubilities of a compound in oil and water phases is called the partition coefficient. The logarithm of the partition coefficients for fifteen polynuclear aromatic hydrocarbon (PAH) compounds in octanol and water are listed in Table VII-12 (page 180).

A study of priority organic compounds commonly found in metal forming operations wastewater streams indicated that incidental removal of these compounds often occurs as a result of oil removal or clarification processes. When all organics analyses from aluminum forming, copper forming, and coil coating are considered, removal of organic compounds by other waste treatment technologies appears to be marginal in many cases. However, when only raw waste concentrations of 0.05 mg/l or greater are considered, incidental organics removal becomes much more apparent. Lower values, those less than 0.05 mg/l, are much more subject to analytical variation, while higher values indicate a significant presence of a given compound. When these factors are taken into account, analysis data indicate that most clarification and oil removal treatment systems remove significant amounts of the organic compounds present in the raw wastewater. The API oil-water separation system and the thermal emulsion breaker (TEB) performed notably in this regard, as shown in the following tabulation (all values in mg/l).

Data from five plant days demonstrate removal of organics by the combined oil skimming and settling operations performed on coil coating wastewaters. Days were chosen where treatment system influent and effluent analyses provided paired data points for oil and grease and the organics present. All organics found at quantifiable levels on those days were included. Further, only those days were chosen where oil and grease raw wastewater concentrations exceeded 10 mg/l and where there was reduction in oil and grease going through the treatment system. All plant sampling days which met the above criteria are included below. The conclusion is that when oil and grease are removed, organics are removed, also.

	Percent Removal	
Plant-Day	Oil & Grease	Organics
1054-3	95.9	98.2
13029-2	98.3	78.0
13029-3	95.1	77.0
38053-1	96.8	81.3
38053-2	98.5	86.3
Mean	96.9	84.2

For aluminum forming wastewaters, effective oil removal technology (such as oil skimming or emulsion breaking) is capable of removing approximately 97 percent of the total toxic organics (TTO) from the raw waste. As shown in the following tabulation, the achievable TTO concentration is approximately 0.690 mg/l. The influent and effluent concentrations presented for each pollutant were taken from the aluminum forming category for several plants with effective oil removal technologies in place. In calculating the concentrations, if only one day's sampling datum was available, that value was used; if two day's sampling data were available, the higher of the values was used; and, if three day's sampling data were available, the mean or the median value was used, whichever was higher. The Agency confident that the 0.690 mg/l value is an appropriate basis for effluent limitations, since the highest values were used in the calculation.

Advantages and Limitations. Skimming as a pretreatment is effective in removing naturally floating waste material. It also improves the performance of subsequent downstream treatments. Many pollutants, particularly dispersed or emulsified oil, will not float "naturally" but require additional treatments. Therefore, skimming alone may not remove all the pollutants capable of being removed by air flotation or other more sophisticated technologies.

Operational Factors. Reliability: Because of its simplicity, skimming is a very reliable technique.

Maintainability: The skimming mechanism requires periodic lubrication, adjustment, and replacement of worn parts.

Solid Waste Aspects: The collected layer of debris must be disposed of by contractor removal, landfill, or incineration. Because relatively large quantities of water are present in the collected wastes, incineration is not always a viable disposal method.

Demonstration Status. Skimming is a common operation utilized extensively by industrial waste treatment systems. Oil removal equipment for skimming as a separate process or in conjunction with chemical emulsion breaking, or dissolved air flotation (discussed below) is in place at 53 canmaking plants.

8. Flotation

Flotation is the process of causing particles such as metal hydroxides or oil to float to the surface of a tank where they can be concentrated and removed. This is accomplished by releasing gas bubbles which attach to the solid particles, increasing their buoyancy and causing them to float. In principle, this process is the opposite of sedimentation. Figure VII-23 (page 216) shows one type of flotation system.

Flotation is used primarily in the treatment of wastewater streams that carry heavy loads of finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which would require abnormally long sedimentation times, may be removed in much less time by flotation.

This process may be performed in several ways: foam, dispersed air, dissolved air, gravity, and vacuum flotation are the most commonly used techniques. Chemical additives are often used to enhance the performance of the flotation process.

The principal difference among types of flotation is the method of generating the minute gas bubbles (usually air) in a suspension of water and small particles. Chemicals may be used to improve the efficiency with any of the basic methods. The following paragraphs describe the dissolved air flotation technique including the method of bubble generation.

Dissolved Air Flotation - In dissolved air flotation, bubbles are produced by releasing air from a supersaturated solution under relatively high pressure. There are two types of contact between the gas bubbles and particles. The first type is predominant in the flotation of flocculated materials and involves the entrapment of rising gas bubbles in the flocculated particles as they increase in size. The bond between the bubble and particle is one of physical capture only. The second type of contact is one of adhesion. Adhesion results from the intermolecular attraction exerted at the interface between the solid particle and gaseous bubble.

Application and Performance. The primary variables for flotation design are pressure, feed solids concentration, and retention period. The suspended solids in the effluent decrease, and the concentration of solids in the float increases with increasing retention period. When the flotation process is used primarily for clarification, a retention period of 20 to 30 minutes usually is adequate for separation and concentration.

Advantages and Limitations. Some advantages of the flotation process are the high levels of solids separation achieved in many applications, the relatively low energy requirements, and the adaptability to meet the treatment requirements of different waste types. Limitations of flotation are that it often requires addition of chemicals to enhance process performance and that it generates large quantities of solid waste.

Operational Factors. Reliability: Flotation systems normally are very reliable with proper maintenance of the sludge collector mechanism and the motors and pumps used for aeration.

Maintainability: Routine maintenance is required on the pumps and motors. The sludge collector mechanism is subject to possible corrosion or breakage and may require periodic replacement.

Solid Waste Aspects: Chemicals are commonly used to aid the flotation process by creating a surface or a structure that can easily adsorb or entrap air bubbles. Inorganic chemicals, such as the aluminum and ferric salts, and activated silica, can bind the particulate matter together and create a structure that can entrap air bubbles. Various organic chemicals can change the nature of either the air-liquid interface or the solid-liquid interface, or both. These compounds usually collect on the interface to bring about the desired changes. The added chemicals plus the particles in solution combine to form a large volume of sludge which must be further treated or properly disposed.

Demonstration Status. Flotation is a fully developed process and is readily available for the treatment of a wide variety of industrial waste streams. Dissolved air flotation is installed at 16 canmaking plants.

9. Chemical Emulsion Breaking

Chemical treatment is often used to break stable oil-water (O-W) emulsions. An O-W emulsion consists of oil dispersed in water, stablized by electrical charges and emulsifying agents. A stable emulsion will not separate or break down without some form of treatment.

Once an emulsion is broken, the difference in specific gravities allows the oil to float to the surface of the water. Solids usually form a layer between the oil and water, since some oil is retained in the solids. The longer the retention time, the more complete and distinct the separation between the oil, solids, and water will be. Often other methods of gravity differential separation, such as air flotation or rotational separation (e.g., centrifugation), are used to enhance and speed separation. A schematic flow diagram of one type of application is shown in Figure VII-31 (page 224).

The major equipment required for chemical emulsion breaking includes: reaction chambers with agitators, chemical storage tanks, chemical feed systems, pump, and piping.

Emulsifiers may be used in the plant to aid in stabilizing or forming emulsions. Emulsifiers are surface-active agents which alter the characteristics of the oil and water interface. These surfactants have rather long polar molecules. One end of the molecule is particularly soluble in water (e.g., carboxyl, sulfate, hydroxyl, or sulfonate groups) and the other end is readily soluble in oils (an organic group which varies greatly with the different surfactant type). Thus, the surfactant emulsifies or suspends the organic material (oil) in water. Emulsifiers also lower the surface tension of the O-W emulsion as a result of solvation and ionic complexing. These emulsions must be destabilized in the treatment system.

Application and Performance. Emulsion breaking is applicable to waste streams containing emulsified oils or lubricants such as rolling and drawing emulsions.

Treatment of spent O-W emulsions involves the use of chemicals to break the emulsion followed by gravity differential separation. Factors to be considered for breaking emulsions are type of chemicals, dosage and sequence of addition, pH, mechanical shear and agitation, heat, and retention time.

Chemicals, e.g., polymers, alum, ferric chloride, and organic emulsion breakers, break emulsions by neutralizing repulsive charges between particles, precipitating or salting out emulsifying agents, or altering the interfacial film between the oil and water so it is readily broken. Reactive cations, e.g., H(+1), Al(+3), Fe(+3), and cationic polymers, are particularly effective in breaking dilute O-W emulsions. Once the charges have been neutralized or the interfacial film broken, the small oil droplets and suspended solids will be adsorbed on the surface of the floc that is formed, or break out and float to the top. Various types of emulsion-breaking chemicals are used for the various types of oils.

If more than one chemical is required, the sequence of addition can make quite a difference in both breaking efficiency and chemical dosages.

pH plays an important role in emulsion breaking, especially if cationic inorganic chemicals, such as alum, are used as coagulants. A depressed pH in the range of 2 to 4 keeps the aluminum ion in its most positive state where it can function most effectively for charge neutralization. After some of the oil is broken free and skimmed, raising the pH into the 6 to 8 range with lime or caustic will cause the aluminum to hydrolyze and precipitate as aluminum hydroxide. This floc entraps or adsorbs destablizied oil droplets which can then be separated from the waste phase. Cationic polymers can break emulsions over a wider pH range and thus avoid acid corrosion and the additional sludge generated from neutralization; however, an inorganic flocculant is usually required to supplement the polymer emulsion breaker's adsorptive properties.

Mixing is important in breaking O-W emulsions. Proper chemical feed and dispersion is required for effective results. Mixing also causes collisions which help break the emulsion, and subsequently helps to agglomerate droplets.

In all emulsions, the mix of two immiscible liquids has a specific gravity very close to that of water. Heating lowers the viscosity and increases the apparent specific gravity differential between oil and water. Heating also increases the frequency of droplet collisons, which helps to rupture the interfacial film.

Oil and grease and toxic organics removal performance data are shown in Tables VII-11 and VII-13 (pages 180 and 181). Data were obtained from sampling at operating plants and a review of the current literature. This type of treatment is proven to be reliable and is considered the current state-of-the-art for aluminum forming emulsified oily wastewaters.

Advantages and Limitions. Advantages gained from the use of chemicals for breaking O-W emulsions are the high removal efficiency potential and the possibility of reclaiming the oily waste. Disadvantages are corrosion problems associated with Acid-alum systems, skilled operator requirements for batch treatment, chemical sludges produced, and poor cost-effectiveness for low oil concentrations.

Operational Factors. Reliability: Chemical emulsion breaking is a very reliable process. The main control parameters, pH and temperature, are fairly easy to control.

Maintainability: Maintenance is required on pumps, motors, and valves, as well as periodic cleaning of the treatment tank to remove any accumulated solids. Energy use is limited to mixers and pumps.

Solid Waste Aspects: The surface oil and oily sludge produced are usually hauled away by a licensed contractor. If the recovered oil has a sufficiently low percentage of water, it may be burned for its fuel value or processed and reused.

Demonstration Status. Chemical emulsion breaking is a fully developed technology widely used in other industry segments, such as metal forming, that use oil-water emulsions. At least 17 canmaking plants have installed this technology.

MAJOR TECHNOLOGY EFFECTIVENESS

The performance of individual treatment technologies was presented above. Performance of operating systems is discussed here. Two different systems are considered: L&S (hydroxide precipitation and sedimentation or lime and settle) and LS&F (hydroxide precipitation, sedimentation and filtration or lime, settle, and filter). Subsequently, an analysis of effectiveness of such systems is made to develop one-day maximum, and ten-day and thirty-day average concentration levels to be used in regulating pollutants. Evaluation of the L&S and the LS&F systems is carried out on the assumption that chemical reduction of chromium, cyanide precipitation, and oil removal are installed and operating properly where appropriate.

L&S Performance -- Combined Metals Data Base

During the development of coil coating and other categorical effluent limitations and standards, chemical analysis data were collected of raw wastewater (treatment influent) and treated wastewater (treatment effluent) from 55 plants (126 data days) sampled by EPA (or its contractor) using EPA sampling and chemical analysis protocols. These data are the initial data base for determining the effectiveness of L&S technology. Each of the plants in the initial data base belongs to at least one of the following industry categories: aluminum forming, battery manufacturing, coil coating, copper forming, electroplating and porcelain enameling. All of the plants employ pH adjustment and hydroxide precipitation using lime or caustic, followed by settling (tank, lagoon or clarifier) for solids removal. Most also add a coagulant or flocculant prior to solids removal. The raw (untreated) wastewater data from canmaking facilities sampled by the Agency were compared to the raw wastewater data from the combined metals facilities. The analysis is discussed below and described in detail in the administrative record supporting this rulemaking.

An analysis of this data was presented in the development documents for the proposed regulations for coil coating and porcelain enameling (January 1981). In response to the proposal, some commenters claimed that it was inappropriate to use data from some categories for regulation of other categories. In response to these comments, the Agency reanalyzed the data. An analysis of variance was applied to the data for the 126 days of sampling to test the hypothesis of homogeneous plant mean raw and treated effluent levels across categories by pollutant. This analysis is described in the report "A Statistical Analysis of the Combined Metals Industries Effluent Data" which is in the administrative record supporting this rulemaking. The main conclusion drawn from the analysis of variance is that, with the exception of electroplating, the categories are generally homogeneous with regard to mean pollutant concentrations in both raw and treated effluent. That is, when data from electroplating facilities are included in the analysis, the hypothesis of homogeneity across categories is rejected. When the electroplating data are removed from the analysis the conclusion changes substantially and the hypothesis of homogeneity across categories is not rejected. On the basis of this analysis, the electroplating data were removed from the data base used to determine limitations. Cases that appeared to be marginally different were not unexpected (such as copper in copper forming and lead in lead battery manufacturing) were accommodated in developing limitations by using the larger values obtained from the marginally different category to characterize the entire data set.

The statistical analysis provides support for the technical engineering judgment that electroplating wastewaters are different from most metal processing wastewaters. These differences may be further explained by differences in the constituents and relative amounts of pollutants in the raw wastewaters. Therefore, the wastewater data derived from plants that only electroplate are not used in developing limitations for the canmaking subcategory.

After removing the electroplating data, data from 21 plants and 52 days of sampling remained. Eleven of these plants and 25 days of sampling are from coil coating operations.

Prior to performing the homogeneity analysis, certain data were deleted from the data base. The following criteria were used in making these deletions:

- Plants where malfunctioning processes or treatment systems at time of sampling were identified.
- Data days where pH was less than 7.0 or TSS was greater than 50 mg/l. (This is a prima facie indication of poor operation).

For the purpose of developing treatment effectiveness, following homogeneity additional deletions were made. These deletions were made, almost exclusively, in cases where effluent data points were associated with raw waste values too low to assure actual pollutant removal (i.e., less than 0.1 mg/l of pollutant in raw waste). A few data points were also eliminated following the homogeneity analysis where malfunctions not previously identified were recognized.

Collectively, these selection criteria insure that the data are from properly operating lime and settle treatment facilities. The remaining data are displayed graphically in Figures VII-4 to VII-12 (Pages 197 to 205). This common or combined metals data base provides a more sound and usable basis for estimating treatment effectiveness and statistical variability of lime and settle technology than the available data from any one category.

One-day Effluent Values

The basis assumption underlying the determination of treatment effectiveness is that the data for a particular pollutant are lognormally distributed by plant. The lognormal has been found to provide a satisfactory fit to plant effluent data in a number of effluent guidelines categories. In the case of the combined metal categories data base, there are too few data from any one plant to verify formally the lognormal assumption. Thus, we assumed measurements of each pollutant from a particular plant, denoted by X, followed a lognormal distribution with log mean μ and log variance σ^2. The mean, variance and 99th percentile of X are then:

$$\text{mean of } X = E(X) = \exp(\mu + \sigma^2/2)$$

$$\text{variance of } X = V(X) = \exp(2\mu + \sigma^2)\,[\exp(\sigma^2)-1]$$

$$\text{99th percentile} = X_{.99} = \exp(\mu + 2.33\sigma)$$

where exp is e, the base of the natural logarithm. The term lognormal is used because the logarithm of X has a normal distribution with mean μ and variance σ^2. Using the basic assumption of lognormality the actual treatment effectiveness was determined using a lognormal distribution that, in a sense, approximates the distribution of an average of the plants in the data base, i.e., an "average plant" distribution. The notion of an "average plant" distribution is not a strict statistical concept but is used here to determine limits that would represent the performance capability of an average of the plants in the data base.

This "average plant" distribution for a particular pollutant was developed as follows: the log mean was determined by taking the average of all the observations for the pollutant across plants. The log variance was determined by the pooled within plant variance. This is the weighted average of the plant variances. Thus, the log mean represents the average of all the data for the pollutant and the log variance represents the average of the plant log variances or average plant variability for the pollutant.

The one day effluent values were determined as follows:

Let X_{ij} = the jth observation on a particular pollutant at plant i where

$i = 1, \ldots, I$
$j = 1, \ldots, J_i$
I = total number of plants
J_i = number of observations at plant i.

Then $Y_{ij} = \ln X_{ij}$

where ln means the natural logarithm.

Then $\bar{y}$ = log mean over all plants

$$= \sum_{i=1}^{I} \sum_{j=1}^{J_i} y_{ij}/n,$$

where n = total number of observations

$$= \sum_{i=1}^{I} J_i$$

and $V(y)$ = pooled log variance

$$= \frac{\sum_{i=1}^{I} (J_i - 1)\, S_i^2}{\sum_{i=1}^{I} (J_i - 1)}$$

where S_i^2 = log variance at plant i

$$= \sum_{j=1}^{J_i} (y_{ij} - \overline{y}_i)^2 / (J_i - 1)$$

$\overline{y}_i$ = log mean at plant i.

Thus, y and V(y) are the log mean and log variance, respectively, of the lognormal distribution used to determine the treatment effectiveness. The estimated mean and 99th percentile of this distribution form the basis for the long term average and daily maximum effluent limitations, respectively. The estimates are

$$\text{mean} = \hat{E}(X) = \exp(\overline{y})\, \psi_n\, (0.5\, V(y))$$

$$\text{99th percentile} = \hat{X}_{.99} = \exp[\overline{y} + 2.33 \sqrt{V(y)}\,]$$

where ψ (.) is a Bessel function and exp is e, the base of the natural logarithms (See Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, Cambridge University Press, 1963). In cases where zeros were present in the data, a generalized form of the lognormal, known as the delta distribution was used (See Aitchison and Brown, op. cit., Chapter 9).

For certain pollutants, this approach was modified slightly to accommodate situations in which a category or categories stood out as being marginally different from the others. For instance, after excluding the electroplating data and other data that did not reflect pollutant removal or proper treatment, the effluent copper data from the copper forming plants were statistically significantly greater than the copper data from the other plants. Thus, copper effluent values shown in Table VII-14 (page 181) are based only on the copper effluent data from the copper forming plants. That is, the log mean for copper is the mean of the logs of all copper values from the copper forming plants only and the log variance is the pooled log variance of the copper forming plant data only. In the case of cadmium, after excluding the electroplating data and data that did not reflect removal or proper treatment, there were insufficient data to estimate the log variance for cadmium. The variance used to determine the values shown in Table VII-14 for cadmium was estimated by pooling the within plant variances for all the other metals. Thus, the cadmium variability is the average of the plant variability averaged over all the other metals. The log mean for cadmium is the mean of the logs of the cadmium observations only. A complete discussion of the data and calculations for all the metals is contained in the administrative record for this rulemaking.

Average Effluent Values

Average effluent values that form the basis for the monthly limitations were developed in a manner consistent with the method used to develop one day treatment effectiveness in that the lognormal distribution used for the one-day effluent values was also used as the basis for the average values. That is, we assume a number of consecutive measurements are drawn from the distribution of daily measurements. The approach used for the 10 measurements values was employed previously for the electroplating category (see "Development document for Existing Sources Pretreatment Standards for the Electroplating Point Source Category" EPA 440/1-79/003, U.S. Environmental Protection Agency, Washington, D.C., August, 1979). That is, the distribution of the average of 10 samples from a lognormal was approximated by another lognormal distribution. Although the approximation is not precise theoretically, there is empirical evidence based on effluent data from a number of categories that the lognormal is an adequate approximation for the distribution of small samples. In the course of previous work the approximation was verified in a computer simulation study. We also note that the average values were developed assuming independence of the observations although no particular sampling scheme was assumed.

Ten-Sample average:

The formulas for the 10-sample limitations were derived on the basis of simple relationships between the mean and variance of the distributions of the daily pollutant measurements and the average of 10 measurements. We assume the daily concentration measurements for a particular pollutant, denoted by X, follow a lognormal distribution with log mean and log variance denoted by μ and σ^2, respectivey. Let $\overline{X}_{10}$ denote the mean of 10 consecutive measurements. The following relationships then hold assuming the daily measurements are independent:

$$\text{mean of } \overline{X}_{10} = E(\overline{X}_{10}) = E(X)$$

$$\text{variance of } \overline{X}_{10} = V(\overline{X}_{10}) = V(X) \div 10.$$

Where E(X) and V(X) are the mean and variance of X, respectively, defined above. We then assume that X_{10} follows a lognormal distribution with log mean μ_{10} and log standard deviation σ_{10}. The mean and variance of X_{10} are then

$$\overline{E}(X_{10}) = \exp(\mu_{10} + 0.5\,\sigma^2_{10})$$
$$V(\overline{X}_{10}) = \exp(2\,\mu_{10} + \sigma^2_{10})\,[\exp(\sigma^2_{10})-1]$$

Now, μ_{10} and σ^2_{10} can be derived in terms of μ and σ^2 as

$$\mu_{10} = \mu + \sigma^2/2 - 0.5 \ln [1+(\exp(\sigma^2 -1)/N]$$
$$\sigma^2_{10} = \ln [1+(\exp(\sigma^2) -1)/N]$$

Therefore, μ_{10} and σ^2_{10} can be estimated using the above relationships and the estimates of μ and σ^2 obtained for the underlying lognormal distribution. The 10 sample limitation value was determined by the estimate of the approximate 99th percentile of the distribution of the 10 sample average given by

$$\widehat{\overline{X}_{10}}(.99) = \exp(\hat{\mu}_{10} + 2.33\,\hat{\sigma}_{10}).$$

where $\hat{\mu}_{10}$ and $\hat{\sigma}_{10}$ are the estimates of μ_{10} and σ_{10}, respectively.

30 Sample Average:

The average values based on 30 measurements are determined on the basis of a statistical result known as the Central Limit Theorem. This Theorem states that, under general and nonrestrictive assumptions, the distribution of a sum of a number of random variables, say n, is approximated by the normal distribution. The approximation improves as the number of variables, n, increases. The Theorem is quite general in that no particular distributional form is assumed for the distribution of the individual variables. In most applications (as in approximating the distribution of 30-day averages) the Theorem is used to approximate the distribution of the average of n observations of a random variable. The result makes it possible to compute approximate probability statements about the average in a wide range of cases. For instance, it is possible to compute a value below which a specified percentage (e.g., 99 percent) of the averages of n observations are likely to fall. Most textbooks state that 25 or 30 observations are sufficient for the approximation to be valid. In applying the Theorem to the distribution of the 30 day average effluent values, we approximate the distribution of the average of 30 observations drawn from the distribution of daily measurements and use the estimated 99th percentile of this distribution. The monthly limitations based on 10 consecutive measurements were determined using the lognormal approximation described above because 10 measurements was, in this case, considered too small a number for use of the Central Limit Theorem.

30 Sample Average Calculation

The formulas for the 30 sample average were based on an application of the Central Limit Theorem. According to the Theorem, the average of 30 observations drawn from the distribution of daily measurements, denoted by $\bar{X}_{30}$, is approximately normally distributed. The mean and variance of $\bar{X}_{30}$ are:

$$\text{mean of } \bar{X}_{30} = E(\bar{X}_{30}) = E(X)$$
$$\text{variance of } \bar{X}_{30} = V(\bar{X}_{30}) = V(X)/30.$$

The 30 sample average value was determined by the estimate of the approximate 99th percentile of the distribution of the 30 sample average given by

$$\hat{\bar{X}}_{30}(.99) = \hat{E}(X) + 2.33 \sqrt{\hat{V}(X) \div 30}$$

where

$$\hat{E}(X) = \exp(\bar{y})\,\psi_n(0.5V(y))$$

and

$$\hat{V}(X) = \exp(2\bar{y})[\,\psi_n(2V(y)) - \psi_n\left(\left(\frac{n-2}{n-1}\right)V(y)\right)].$$

The formulas for E(X) and V(X) are estimates of E(X) and V(X) respectively given in Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, Cambridge University Press, 1963, page 45.

Application

In response to the proposed coil coating and porcelain enameling regulations, the Agency received comments pointing out that permits usually required less than 30 samples to be taken during a month while the monthly average used as the basis for permits and pretreatment requirements usually is based on the average of 30 samples.

In applying the treatment effectiveness values to regulations we have considered the comments, examined the sampling frequency required by many permits and considered the change in values of averages depending on the number of consecutive sampling days in the averages. The most common frequency of sampling required in permits is about ten samples per month or slightly greater than twice weekly. The 99th percentiles of the distribution of averages of ten consecutive sampling days are not substantially different from the 99th percentile of the distribution's 30 day average. (Compared to the one-day maximum, the ten-day average is about 80 percent of the difference between one and 30 day values). Hence the ten day average provides a reasonable basis for a monthly average limitation and is typical of the sampling frequency required by existing permits.

The monthly average limitation is to be achieved in all permits and pretreatment standards regardless of the number of samples required to be analyzed and averaged by the permit or the pretreatment authority.

Additional Pollutants

A number of other pollutant parameters were considered with regard to the performance of lime and settle treatment systems in removing them from industrial wastewater. Performance data for these parameters is not readily available, so data available to the Agency in other categories has been selectively used to determine the long term average performance of lime and settle technology for each pollutant. These data indicate that the concentrations shown in Table VII-15 (page 182) are reliably attainable with hydroxide precipitation and settling. The precipitation of silver appears to be accomplished by alkaline chloride precipitation and adequate chloride ions must be available for this reaction to occur.

In establishing which data were suitable for use in Table VII-14 two factors were heavily weighed; (1) the nature of the wastewater; (2) and the range of pollutants or pollutant matrix in the raw wastewater. These data have been selected from processes that generate dissolved metals in the wastewater and which are generally free from complexing agents. The pollutant matrix was evaluated by comparing the concentrations of pollutants found in the raw wastewaters with the range of pollutants in the raw wastewaters of the combined metals data set. These data are displayed in Tables VII-16 (page 182) and VII-17 (page 183) and indicate that there is sufficient similarity in the raw wastes to logically assume transferability of the treated pollutant concentrations to the combined metals data base. The available date on these added pollutants do not allow homogeneity analysis as was performed on the combined metals data base. The data source for each added pollutant is discussed separately.

Antimony (Sb) - The achievable performance for antimony is based on data from a battery and secondary lead plant. Both EPA sampling data and recent permit data (1978-1982) confirm the achievability of 0.7 mg/l in the battery manufacturing wastewater matrix included in the combined data set.

Arsenic (As) - The achievable performance of 0.5 mg/l for arsenic is based on permit data from two nonferrous metals manufacturing plants. The untreated wastewater matrix shown in Table VII-17 (page 183) is comparable with the combined data set matrix.

Beryllium (Be) - The treatability of beryllium is transferred from the nonferrous metals manufacturing industry. The 0.3 mg/l performance is achieved at a beryllium plant with the comparable untreated wastewater matrix shown in Table VII-17.

Mercury (Hg) - The 0.06 mg/l treatability of mercury is based on data from four battery plants. The untreated wastewater matrix at these plants was considered in the combined metals data set.

Selenium (Se) - The 0.30 mg/l treatability of selenium is based on recent permit data from one of the nonferrous metals manufacturing plants also used for antimony performance. The untreated wastewater matrix for this plant is shown in Table VII-17.

Silver - The treatability of silver is based on a 0.1 mg/l treatability estimate from the inorganic chemicals industry. Additional data supporting a treatability as stringent or more stringent than 0.1 mg/l is also available from seven nonferrous metals manufacturing plants. The untreated wastewater matrix for these plants is comparable and summarized in Table VII-17.

Thallium (Tl) - The 0.50 mg/l treatability for thallium is transferred from the inorganic chemicals industry. Although no untreated wastewater data are available to verify comparability with the combined metals data set plants, no other sources of data for thallium treatability could be identified.

Aluminum (Al) - The 1.11 mg/l treatability of aluminum is based on the mean performance of one aluminum forming plant and one coil coating plant. Both of the plants are from categories considered in the combined metals data set, assuring untreated wastewater matrix comparability.

Cobalt (Co) - The 0.05 mg/l treatability is based on nearly complete removal of cobalt at a porcelain enameling plant with a mean untreated wastewater cobalt concentration of 4.31 mg/l. In this case, the analytical detection using aspiration techniques for this pollutant is used as the basis of the treatability. Porcelain enameling was considered in the combined metals data base, assuring untreated wastewater matrix comparability.

Fluoride (F) - The 14.5 mg/l treatability of fluoride is based on the mean performance of an electronics and electrical component manufacturing plant. The untreated wastewater matrix for this plant shown in Table VII-17 is comparable to the combined metals data set.

Phosphorus (P) - The 4.08 mg/l treatability of phosphorus is based on the mean of 44 samples including 19 samples from the Combined Metals Data Base and 25 samples from the electroplating data base. Inclusion of electroplating data with the combined metals data was considered appropriate, since the removal mechanism for phosphorus is a precipitation reaction with calcium rather than hydroxide.

CANMAKING DATA - To determine the applicability of the combined metals data base to canmaking an analysis was made using the canmaking data shown in Table V-7 (page 48). Canmaking was treated as an additional category in the combined metals data base and the same statistical procedures used to assess homogeneity of the combined metals data were performed. The results indicate substantial homogeneity among untreated wastewater data from canmaking and the combined metals categories. In fact, the addition of canmaking as another category had no effect on the overall tests of homogeneity. That is, the results of overall homogeneity were the same with and without the canmaking data. These results support the hypothesis of similar raw waste characteristics among canmaking and the combined metals categories and suggest that lime and settle treatment would reduce concentrations of toxic metal pollutants in canmaking to levels comparable to those achievable by lime and settle in the combined metals categories. Additionally, the concentrations of aluminum, fluoride and phosphorus found in canmaking raw wastewaters are comparable to or lower than values for these pollutants found in the combined metals data base suggesting that L&S technology would remove these pollutants to the levels shown in Table VII-21. Similarly, the lime, settle, and filter discussion which follows is applicable to canmaking wastewater the same as any other wastewater in the common metals data base. The analysis of the canmaking wastewater data and of the combined metals data base is detailed in the administrative record of this rulemaking.

LS&F Performance

Tables VII-18 and VII-19 (pages 184 and 185) show long term data from two plants which have well operated precipitation-settling treatment followed by filtration. The wastewaters from both plants contain pollutants from metals processing and finishing operations (multi-category). Both plants reduce hexavalent chromium before neutralizing and precipitating metals with lime. A clarifier is used to remove much of the solids load and a filter is used to "polish" or complete removal of suspended solids. Plant A uses a pressure filter, while Plant B uses a rapid sand filter.

Raw wastewater data was collected only occasionally at each facility and the raw wastewater data is presented as an indication of the nature of the wastewater treated. Data from plant A was received as a statistical summary and is presented as received. Raw laboratory data was collected at plant B and reviewed for spurious points and discrepancies. The method of treating the data base is discussed below under lime, settle, and filter treatment effectiveness.

Table VII-20 (page 186) shows long-term data for zinc and cadmium removal at Plant C, a primary zinc smelter, which operates a LS&F system. This data represents about 4 months (103 data days) taken immediately before the smelter was closed. It has been arranged similarily to Plants A and B for comparison and use.

These data are presented to demonstrate the performance of precipitation-settling-filtration (LS&F) technology under actual operating conditions and over a long period of time.

It should be noted that the iron content of the raw wastewater of plants A and B is high while that for Plant C is low. This results, for plants A and B, in coprecipitation of toxic metals with iron. Precipitation using high-calcium lime for pH control yields the results shown above. Plant operating personnel indicate that this chemical treatment combination (sometimes with polymer assisted coagulation) generally produces better and more consistant metals removal than other combinations of sacrificial metal ions and alkalis.

The LS&F performance data presented here are based on systems that provide polishing filtration after effective L&S treatment. We have previously shown that L&S treatment is equally applicable to wastewaters from the five categories because of the homogeneity of its raw and treated wastewaters, and other factors. Because of the similarity of the wastewaters after L&S treatment, the Agency believes these wastewaters are equally amenable to treatment using polishing filters added to the L&S treatment system. The Agency concludes that LS&F data based on porcelain enameling and non-ferrous smelting and refining is directly applicable to the aluminum forming, copper forming, battery manufacturing, coil coating, and metal molding and casting categories, and the canmaking subcategory as well as it is to porcelain enameling and nonferrous melting and refining.

Analysis of Treatment System Effectiveness

Data are presented in Table VII-14 showing the mean, one day, 10 day, and 30 day values for nine pollutants examined in the L&S combined metals data base. The pooled variability factor for seven metal pollutants (excluding cadmium because of the small number of data points) was determined and is used to estimate one day, 10 day and 30 day values. (The variability factor is the ratio of the value of concern to the mean: the pooled variability factors are: one day maximum - 4.100; ten day average - 1.821; and 30 day average - 1.618.) For values not calculated from the common data base as previously discussed, the mean value for pollutants shown in Table VII-15 were multiplied by the variability factors to derive the value to obtain the one, ten and 30 day values. These are tabulated in Table VII-21.

LS&F technology data are presented in Tables VII-18 and VII-19. These data represent two operating plants (A and B) in which the technology has been installed and operated for some years. Plant A data was received as a statistical summary and is presented without change. Plant B data was received as raw laboratory analysis data. Discussions with plant personnel indicated that operating experiments and changes in materials and reagents and occasional operating errors had occured during the data collection period. No specific information was available on those variables. To sort out high values probably caused by methodological factors from random statistical variability, or data noise, the plant B data were analyzed. For each of four pollutants (chromium, nickel, zinc, and iron), the mean and standard deviation (sigma) were calculated for the entire data set. A data day was removed from the complete data set when any individual pollutant concentration for that day exceeded the sum of the mean plus three sigma for that pollutant. Fifty-one data days (from a total of about 1300) were eliminated by this method.

Another approach was also used as a check on the above method of eliminating certain high values. The minimum values of raw wastewater concentrations from Plant B for the same four pollutants were compared to the total set of values for the corresponding pollutants. Any day on which the pollutant concentration exceeded the minimum value selected from raw wastewater concentrations for that pollutant was discarded. Forty-five days of data were eliminated by that procedure. Forty-three days of data in common were eliminated by either procedures. Since common engineering practice (mean plus 3 sigma) and logic (treated wastewater concentrations should be less than raw wastewater concentrations) seem to coincide, the data base with the 51 spurious data days eliminated is the basis for all further analysis. Range, mean, standard deviation and mean plus two standard deviations are shown in Tables VII-18 and VII-19 for Cr, Cu, Ni, Zn and Fe.

The Plant B data was separated into 1979, 1978, and total data base (six years) segments. With the statistical analysis from Plant A for 1978 and 1979 this in effect created five data sets in which there is some overlap between the individual years and total data sets from Plant B. By comparing these five parts it is apparent that they are quite similar and all appear to be from the same family of numbers. The largest mean found among the factors are: one day maximum - 4.100; ten day average - 1.821; and 30 day average - 1.618.) For values not calculated from the common data base as previously discussed, the mean value for pollutants shown in Table VII-15 were multiplied by the variability factors to derive the value to obtain the one, ten and 30 day values. These are tabulated in Table VII-21.

LS&F technology data are presented in Tables VII-18 and VII-19. These data represent two operating plants (A and B) in which the technology has been installed and operated for some years. Plant A data was received as a statistical summary and is presented without change. Plant B data was received as raw laboratory analysis data. Discussions with plant personnel indicated that operating experiments and changes in materials and reagents and occasional operating errors had occured during the data collection period. No specific information was available on those variables. To sort out high values probably caused by methodological factors from random statistical variability, or data noise, the plant B data were analyzed. For each of four pollutants (chromium, nickel, zinc, and iron), the mean and standard deviation (sigma) were calculated for the entire data set. A data day was removed from the complete data set when any individual pollutant concentration for that day exceeded the sum of the mean plus three sigma for that pollutant. Fifty-one data days (from a total of about 1300) were eliminated by this method.

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The Plant B data was separated into 1979, 1978, and total data base (six years) segments. With the statistical analysis from Plant A for 1978 and 1979 this in effect created five data sets in which there is some overlap between the individual years and total data sets from Plant B. By comparing these five parts it is apparent that they are quite similar and all appear to be from the same family of numbers. The largest mean found among the five data sets for each pollutant was selected as the long term mean for LS&F technology and is used as the LS&F mean in Table VII-21.

Plant C data was used as a basis for cadmium removal performance and as a check on the zinc values derived from Plants A and B. The cadmium data is displayed in Table VII-20 (page 186) and is incorporated into Table VII-21 for LS&F. The zinc data was analyzed for compliance with the 1-day and 30-day values in Table VII-20; no zinc value of the 103 data points exceeded the 1-day zinc value of 1.02 mg/l. The 103 data points were separated into blocks of 30 points and averaged. Each of the 3 full 30-day averages was less than the Table VII-21 value of 0.31 mg/l. Additionally the Plant C raw wastewater pollutant concentrations (Table VII-19) are well within the range of raw wastewater concentrations of the combined metals data base (Table VII-15), further supporting the conclusion that Plant C wastewater data is compatible with similar data from Plants A and B.

Concentration values for regulatory use are displayed in Table VII-21. Mean one day, ten day and 30 day values for L&S for nine pollutants were taken from Table VII-13; the remaining L&S values were developed using the mean values in Table VII-15 and the mean variability factors discussed above.

LS&F mean values for Cd, Cr, Ni, Zn and Fe are derived from plants A, B, and C as discussed above. One, ten and thirty day values are derived by applying the variability factor developed from the pooled data base for the specific pollutant to the mean for that pollutant. Other LS&F values are calculated using the long term average or mean and the appropriate variability factors. Mean values for LS&F for pollutants not already discussed are derived by reducing the L&S mean by one-third. The one-third reduction was established after examining the percent reduction in concentrations going from L&S to LS&F data for Cd, Cr, Ni, Zn, and Fe. The average reduction is 0.3338 or one third.

Copper levels achieved at Plants A and B may be lower than generally achievable because of the high iron content and low copper content of the raw wastewaters. Therefore, the mean concentration value achieved is not used; LS&F mean used is derived from the L&S technology.

L&S cyanide mean levels shown in Table VII-8 are ratioed to one day, ten day and 30 day values using mean variability factors. LS&F mean cyanide is calculated by applying the ratios of removals L&S and LS&F as discussed previously for LS&F metals limitations. The cyanide performance was arrived at by using the average metal variability factors. The treatment method used here is cyanide precipitation. Because cyanide precipitation is limited by the same physical processes as the metal precipitation, it is expected that the variabilities will be similar. Therefore, the average of the metal variability factors has been used as a basis for calculating the cyanide one day, ten day and thirty day average treatment effectiveness values.

The filter performance for removing TSS as shown in Table VII-9 (page 179) yields a mean effluent concentration of 2.61 mg/l and calculates to a 10 day average of 4.33, 30 day average of 3.36 mg/l; a one day maximum of 8.88. These calculated values more than amply support the classic values of 10 and 15, respectively, which are used for LS&F.

Although iron concentrations were decreased in some LS&F operations, some facilities using that treatment introduce iron compounds to aid settling. Therefore, the one day, ten day and 30 day values for iron at LS&F were held at the L&S level so as to not unduly penalize the operations which use the relatively less objectionable iron compounds to enhance removals of toxic metals.

MINOR TECHNOLOGIES

Several other treatment technologies were considered for possible application in BPT or BAT. These technologies are presented here with a full discussion for most of them. A few are described only briefly because of limited technical development.

10. Carbon Adsorption

The use of activated carbon to remove dissolved organics from water and wastewater is a long demonstrated technology. It is one of the most efficient organic removal processes available. This sorption process is reversible, allowing activated carbon to be regenerated for reuse by the application of heat and steam or solvent. Activated carbon has also proved to be an effective adsorbent for many toxic metals, including mercury. Regeneration of carbon which has adsorbed significant metals, however, may be difficult.

The term activated carbon applies to any amorphous form of carbon that has been specially treated to give high adsorption capacities. Typical raw materials include coal, wood, coconut shells, petroleum base residues and char from sewage sludge pyrolysis. A carefully controlled process of dehydration, carbonization, and oxidation yields a product which is called activated carbon. This material has a high capacity for adsorption due primarily to the large surface area available for adsorption, 500-1500 m^2/g resulting from a large number of internal pores. Pore sizes generally range from 10-100 angstroms in radius.

Activated carbon removes contaminants from water by the process of adsorption, or the attraction and accumulation of one substance on the surface of another. Activated carbon preferentially adsorbs organic compounds and, because of this selectivity, is particularly effective in removing organic compounds from aqueous solution.

Carbon adsorption requires pretreatment to remove excess suspended solids, oils, and greases. Suspended solids in the influent should be less than 50 mg/l to minimize backwash requirements; a downflow carbon bed can handle much higher levels (up to 2000 mg/l), but requires frequent backwashing. Backwashing more than two or three times a day is not desirable; at 50 mg/l suspended solids one backwash will suffice. Oil and grease should be less than about 10 mg/l. A high level of dissolved inorganic material in the influent may cause problems with thermal carbon reactivation (i.e., scaling and loss of activity) unless appropriate preventive steps are taken. Such steps might include pH control, softening, or the use of an acid wash on the carbon prior to reactivation.

Activated carbon is available in both powdered and granular form. An adsorption column packed with granular activated carbon is shown in Figure VII-17 (page 210). Powdered carbon is less expensive per unit weight and may have slightly higher adsorption capacity, but it is more difficult to handle and to regenerate.

Application and Performance. Carbon adsorption is used to remove mercury from wastewaters. The removal rate is influenced by the mercury level in the influent to the adsorption unit. Removal levels found at three manufacturing facilities are shown in Table VII-24 (page 190). In the aggregate these data indicate that very low effluent levels could be attained from any raw waste by use of multiple adsorption stages. This is characteristic of adsorption processes.

Isotherm tests have indicated that activated carbon is very effective in adsorbing 65 percent of the organic priority pollutants and is reasonably effective for another 22 percent. Specifically, for the organics of particular interest, activated carbon was very effective in removing all phthalates. It was resonably effective on 1,1,1-trichloroethane, bis(2-chloroethyl)ether, and toluene.

Table VII-22 (page 188) summarizes the treatability effectiveness for most of the organic priority pollutants by activated carbon as compiled by EPA. Table VII-23 (page 189) summarizes classes of organic compounds together with examples of organics that are readily adsorbed on carbon. Table VII-24 lists the effectiveness of activated carbon.

Advantages and Limitations. The major benefits of carbon treatment include applicability to a wide variety of organics, and high removal efficiency. Inorganics such as cyanide, chromium, and mercury are also removed effectively. Variations in concentration and flow rate are well tolerated. The system is compact, and recovery of adsorbed materials is sometimes practical. However, destruction of adsorbed compounds often occurs during thermal regeneration. If carbon cannot be thermally desorbed, it must be disposed of along with any adsorbed pollutants. The capital and operating costs of thermal regeneration are relatively high. Cost surveys show that thermal regeneration is generally economical when carbon usage exceeds about 1,000 lb/day. Carbon cannot remove low molecular weight or highly soluble organics. It also has a low tolerance for suspended solids, which must be removed to at least 50 mg/l in the influent water.

Operational Factors. Reliability: This system should be very reliable with upstream protection and proper operation and maintenance procedures.

Maintainability: This system requires periodic regeneration or replacement of spent carbon and is dependent upon raw waste load and process efficiency.

Solid Waste Aspects: Solid waste from this process is contaminated activated carbon that requires disposal. Carbon undergoes regeneration, reduces the solid waste problem by reducing the frequency of carbon replacement.

Demonstration Status. Carbon adsorption systems have been demonstrated to be practical and economical in reducing COD, BOD and related parameters in secondary municipal and industrial wastewaters; in removing toxic or refractory organics from isolated industrial wastewaters; in removing and recovering certain organics from wastewaters; and in the removing and some times recovering, of selected inorganic chemicals from aqueous wastes. Carbon adsorption is a viable and economic process for organic waste streams containing up to 1 to 5 percent of refractory or toxic organics. Its applicability for removal of inorganics such as metals has also been demonstrated.

11. Centrifugation

Centrifugation is the application of centrifugal force to separate solids and liquids in a liquid-solid mixture or to effect concentration of the solids. The application of centrifugal force is effective because of the density differential normally found between the insoluble solids and the liquid in which they are contained. As a waste treatment procedure, centrifugation is applied to dewatering of sludges. One type of centrifuge is shown in Figure VII-18 (page 211).

There are three common types of centrifuges: the disc, basket, and conveyor type. All three operate by removing solids under the influence of centrifugal force. The fundamental difference between the three types is the method by which solids are collected in and discharged from the bowl.

In the disc centrifuge, the sludge feed is distributed between narrow channels that are present as spaces between stacked conical discs. Suspended particles are collected and discharged continuously through small orifices in the bowl wall. The clarified effluent is discharged through an overflow weir.

A second type of centrifuge which is useful in dewatering sludges is the basket centrifuge. In this type of centrifuge, sludge feed is introduced at the bottom of the basket, and solids collect at the bowl wall while clarified effluent overflows the lip ring at the top. Since the basket centrifuge does not have provision for continuous discharge of collected cake, operation requires interruption of the feed for cake discharge for a minute or two in a 10 to 30 minute overall cycle.

The third type of centrifuge commonly used in sludge dewatering is the conveyor type. Sludge is fed through a stationary feed pipe into a rotating bowl in which the solids are settled out against the bowl wall by centrifugal force. From the bowl wall, they are moved by a screw to the end of the machine, at which point whey are discharged. The liquid effluent is discharged through ports after passing the length of the bowl under centrifugal force.

Application And Performance. Virtually all industrial waste treatment systems producing sludge can use centrifugation to dewater it. Centrifugation is currently being used by a wide range of industrial concerns.

The performance of sludge dewatering by centrifugation depends on the feed rate, the rotational velocity of the drum, and the sludge composition and concentration. Assuming proper design and operation, the solids content of the sludge can be increased to 20-35 percent.

Advantages And Limitations. Sludge dewatering centrifuges have minimal space requirements and show a high degree of effluent clarification. The operation is simple, clean, and relatively inexpensive. The area required for a centrifuge system installation is less than that required for a filter system or sludge drying bed of equal capacity, and the initial cost is lower.

Centrifuges have a high power cost that partially offsets the low initial cost. Special consideration must also be given to providing sturdy foundations and soundproofing because of the vibration and noise that result from centrifuge operation. Adequate electrical power must also be provided since large motors are required. The major difficulty encountered in the operation of centrifuges has been the disposal of the concentrate which is relatively high in suspended, non-settling solids.

Operational Factors. Reliability: Centrifugation is highly reliable with proper control of factors such as sludge feed, consistency, and temperature. Pretreatment such as grit removal and coagulant addition may be necessary, depending on the composition of the sludge and on the type of centrifuge employed.

Maintainability: Maintenance consists of periodic lubrication, cleaning, and inspection. The frequency and degree of inspection required varies depending on the type of sludge solids being dewatered and the maintenance service conditions. If the sludge is abrasive, it is recommended that the first inspection of the rotating assembly be made after approximately 1,000 hours of operation. If the sludge is not abrasive or corrosive, then the initial inspection might be delayed. Centrifuges not equipped with a continuous sludge discharge system require periodic shutdowns for manual sludge cake removal.

Solid Waste Aspects: Sludge dewatered in the centrifugation process may be disposed of by landfill. The clarified effluent (centrate), if high in dissolved or suspended solids, may require further treatment prior to discharge.

Demonstration Status. Centrifugation is currently used in a great many commercial applications to dewater sludge. Work is underway to improve the efficiency, increase the capacity, and lower the costs associated with centrifugation.

12. Coalescing

The basic principle of coalescence involves the preferential wetting of a coalescing medium by oil droplets which accumulate on the medium and then rise to the surface of the solution as they combine to form larger particles. The most important requirements for coalescing media are wettability for oil and large surface area. Monofilament line is sometimes used as a coalescing medium.

Coalescing stages may be integrated with a wide variety of gravity oil separation devices, and some systems may incorporate several coalescing stages. In general a preliminary oil skimming step is desirable to avoid overloading the coalescer.

One commercially marketed system for oily waste treatment combines coalescing with inclined plate separation and filtration. In this system, the oily wastes flow into an inclined plate settler. This unit consists of a stack of inclined baffle plates in a cylindrical container with an oil collection chamber at the top. The oil droplets rise and impinge upon the undersides of the plates. They then migrate upward to a guide rib which directs the oil to the oil collection chamber, from which oil is discharged for reuse or disposal.

The oily water continues on through another cylinder containing replaceable filter cartridges, which remove suspended particles from the waste. From there the wastewater enters a final cylinder in which the coalescing material is housed. As the oily water passes through the many small, irregular, continuous passages in the coalescing material, the oil droplets coalesce and rise to an oil collection chamber.

Application and Performance. Coalescing is used to treat oily wastes which do not separate readily in simple gravity systems. The three stage system described above has achieved effluent concentrations of 10-15 mg/l oil and grease from raw waste concentrations of 1000 mg/l or more.

Advantages and Limitations. Coalescing allows removal of oil droplets too finely dispersed for conventional gravity separation-skimming technology. It also can significantly reduce the residence times (and therefore separator volumes) required to achieve separation of oil from some wastes. Because of its simplicity, coalescing provides generally high reliability and low capital and operating costs. Coalescing is not generally effective in removing soluble or chemically stabilized emulsified oils. To avoid plugging, coalescers must be protected by pretreatment from very high concentrations of free oil and grease and suspended solids. Frequent replacement of prefilters may be necessary when raw waste oil concentrations are high.

Operational Factors. Reliability: Coalescing is inherently highly reliable since there are no moving parts, and the coalescing substrate (monofilament, etc.) is inert in the process and therefore not subject to frequent regeneration or replacement requirements. Large loads or inadequate pretreatment, however, may result in plugging or bypass of coalescing stages.

Maintainability: Maintenance requirements are generally limited to replacement of the coalescing medium on an infrequent basis.

Solid Waste Aspects: No appreciable solid waste is generated by this process.

Demonstration Status. Coalescing has been fully demonstrated in industries generating oily wastewater.

13. Cyanide Oxidation By Chlorine

Cyanide oxidation using chlorine is widely used in industrial waste treatment to oxidize cyanide. Chlorine can be utilized in either the elemental or hypochlorite forms. This classic procedure can be illustrated by the following two step chemical reaction:

1. $Cl_2 + NaCN + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O$

2. $3Cl_2 + 6NaOH + 2NaCNO \rightarrow 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$

The reaction presented as equation (2) for the oxidation of cyanate is the final step in the oxidation of cyanide. A complete system for the alkaline chlorination of cyanide is shown in Figure VII-19 (page 212).

The alkaline chlorination process oxidizes cyanides to carbon dioxide and nitrogen. The equipment often consists of an equalization tank followed by two reaction tanks, although the reaction can be carried out in a single tank. Each tank has an electronic recorder-controller to maintain required conditions with respect to pH and oxidation reduction potential (ORP). In the first reaction tank, conditions are adjusted to oxidize cyanides to cyanates. To effect the reaction, chlorine is metered to the reaction tank as required to maintain the ORP in the range of 350 to 400 millivolts, and 50 percent aqueous caustic soda is added to maintain a pH range of 9.5 to 10. In the second reaction tank, conditions are maintained to oxidize cyanate to carbon dioxide and nitrogen. The desirable ORP and pH for this reaction are 600 millivolts and a pH of 8.0. Each of the reaction tanks is equipped with a propeller agitator designed to provide approximately one turnover per minute. Treatment by the batch process is accomplished by using two tanks, one for collection of water over a specified time period, and one tank for the treatment of an accumulated batch. If dumps of concentrated wastes are frequent, another tank may be required to equalize the flow to the treatment tank. When the holding tank is full, the liquid is transferred to the reaction tank for treatment. After treatment, the supernatant is discharged and the sludges are collected for removal and ultimate disposal.

Application and Performance. The oxidation of cyanide waste by chlorine is a classic process and is found in most industrial plants using cyanide. This process is capable of achieving effluent levels that are nondetectable. The process is potentially applicable to canmaking facilities where cyanide is a component in conversion coating formulations.

Advantages and Limitations. Some advantages of chlorine oxidation for handling process effluents are operation at ambient temperature, suitability for automatic control, and low cost. Disadvantages include the need for careful pH control, possible chemical interference in the treatment of mixed wastes, and the potential hazard of storing and handling chlorine gas.

Operational Factors. Reliability: Chlorine oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge and recalibration of instruments.

Solid Waste Aspects: There is no solid waste problem associated with chlorine oxidation.

Demonstration Status. The oxidation of cyanide wastes by chlorine is a widely used process in plants using cyanide in cleaning and metal processing baths.

14. Cyanide Oxidation By Ozone

Ozone is a highly reactive oxidizing agent which is approximately ten times more soluble than oxygen on a weight basis in water. Ozone may be produced by several methods, but the silent electrical discharge method is predominant in the field. The silent electrical discharge process produces ozone by passing oxygen or air between electrodes separated by an insulating material. A complete ozonation system is represented in Figure VII-20 (page 213).

Application and Performance. Ozonation has been applied commercially to oxidize cyanides, phenolic chemicals, and organometal complexes. Its applicability to photographic wastewaters has been studied in the laboratory with good results. Ozone is used in industrial waste treatment primarily to oxidize cyanide to cyanate and to oxidize phenols and dyes to a variety of colorless nontoxic products.

Oxidation of cyanide to cyanate is illustrated below:

$$CN^- + O_3 \longrightarrow CNO^- + O_2$$

Continued exposure to ozone will convert the cyanate formed to carbon dioxide and ammonia; however, this is not economically practical.

Ozone oxidation of cyanide to cyanate requires 1.8 to 2.0 pounds ozone per pound of CN^-; complete oxidation requires 4.6 to 5.0 pounds ozone per pound of CN^-. Zinc, copper, and nickel cyanides are easily destroyed to a nondetectable level, but cobalt and iron cyanides are more resistant to ozone treatment.

Advantages and Limitations. Some advantages of ozone oxidation for handling process effluents are its suitability to automatic control and on-site generation and the fact that reaction products are not chlorinated organics and no dissolved solids are added in the treatment step. Ozone in the presence of activated carbon, ultraviolet, and other promoters shows promise of reducing reaction time and improving ozone utilization, but the process at present is limited by high capital expense, possible chemical interference in the treatment of mixed wastes, and an energy requirement of 25 kwh/kg of ozone generated. Cyanide is not economically oxidized beyond the cyanate form.

Operational Factors. Reliability: Ozone oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge, and periodic renewal of filters and desiccators required for the input of clean dry air; filter life is a function of input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may be necessary. Dewatering of sludge generated in the ozone oxidation process or in an "in line" process may be desirable prior to disposal.

15. Cyanide Oxidation By Ozone With UV Radiation

One of the modifications of the ozonation process is the simultaneous application of ultraviolet light and ozone for the treatment of wastewater, including treatment of halogenated organics. The combined action of these two forms produces reactions by photolysis, photosensitization, hydroxylation, oxygenation and oxidation. The process is unique because several reactions and reaction species are active simultaneously.

Ozonation is facilitated by ultraviolet absorption because both the ozone and the reactant molecules are raised to a higher energy state so that they react more rapidly. In addition, free radicals for use in the reaction are readily hydrolyzed by the water present. The energy and reaction intermediates created by the introduction of both ultraviolet and ozone greatly reduce the amount of ozone required compared with a system using ozone alone. Figure VII-21 (page 214) shows a three-stage UV-ozone system. A system to treat mixed cyanides requires pretreatment that involves chemical coagulation, sedimentation, clarification, equalization, and pH adjustment.

Application and Performance. The ozone-UV radiation process was developed primarily for cyanide treatment in the electroplating and color photo-processing areas. It has been successfully applied to mixed cyanides and organics from organic chemicals manufacturing processes. The process is particularly useful for treatment of complexed cyanides such as ferricyanide, copper cyanide and nickel cyanide, which are resistant to ozone alone.

Ozone combined with UV radiation is a relatively new technology. Four units are currently in operation and all four treat cyanide bearing waste.

Ozone-UV treatment could be used in canmaking plants to destroy cyanide present in waste streams from some conversion coating operations.

16. Cyanide Oxidation By Hydrogen Peroxide

Hydrogen peroxide oxidation removes both cyanide and metals in cyanide containing wastewaters. In this process, cyanide bearing waters are heated to 49 - 54°C (120 - 130°F) and the pH is adjusted to 10.5 - 11.8. Formalin (37 percent formaldehyde) is added while the tank is vigorously agitated. After 2-5 minutes, a proprietary peroxygen compound (41 percent hydrogen peroxide with a catalyst and additives) is added. After an hour of mixing, the reaction is complete. The cyanide is converted to cyanate and the metals are precipitated as oxides or hydroxides.

The metals are then removed from solution by either settling or filtration.

The main equipment required for this process is two holding tanks equipped with heaters and air spargers or mechanical stirrers. These tanks may be used in a batch or continuous fashion, with one tank being used for treatment while the other is being filled. A settling tank or a filter is needed to concentrate the precipitate.

Application and Performance. The hydrogen peroxide oxidation process is applicable to cyanidebearing wastewaters, especially those containing metal-cyanide complexes. In terms of waste reduction performance, this process can reduce total cyanide to less than 0.1 mg/l and the zinc or cadmium to less than 1.0 mg/l.

Advantages and Limitations. Chemical costs are similar to those for alkaline chlorination using chlorine and lower than those for treatment with hypochlorite. All free cyanide reacts and is completely oxidized to the less toxic cyanate state. In addition, the metals precipitate and settle quickly, and they may be recoverable in many instances. However, the process requires energy expenditures to heat the wastewater prior to treatment.

Demonstration Status. This treatment process was introduced in 1971 and is used in several facilities.

17. Evaporation

Evaporation is a concentration process. Water is evaporated from a solution, increasing the concentration of solute in the remaining solution. If the resulting water vapor is condensed back to liquid water, the evaporation-condensation process is called distillation. However, to be consistent with industry terminology, evaporation is used in this report to describe both processes. Both atmospheric and vacuum evaporation are commonly used in industry today. Specific evaporation techniques are shown in Figure VII-22 (page 215) and discussed below.

Atmospheric evaporation could be accomplished simply by boiling the liquid. However, to aid evaporation, heated liquid is sprayed on an evaporation surface, and air is blown over the surface and subsequently released to the atmosphere. Thus, evaporation occurs by humidification of the air stream, similar to a drying process. Equipment for carrying out atmospheric evaporation is quite similar for most applications. The major element is generally a packed column with an accumulator bottom. Accumulated wastewater is pumped from the base of the column, through a heat exchanger, and back into the top of the column, where it is sprayed into the packing. At the same time, air drawn upward through the packing by a fan is heated as it contacts the hot liquid. The liquid partially vaporizes and humidifies the air stream. The fan then blows the hot, humid air to the outside atmosphere. A scrubber is often unnecessary because the packed column itself acts as a scrubber.

Another form of atmospheric evaporator also works on the air humidification principle, but the evaporated water is recovered for reuse by condensation. These air humidification techniques operate well below the boiling point of water and can utilize waste process heat to supply the energy required.

In vacuum evaporation, the evaporation pressure is lowered to cause the liquid to boil at reduced temperature. All of the water vapor is condensed and, to maintain the vacuum condition, noncondensible gases (air in particular) are removed by a vacuum pump. Vacuum evaporation may be either single or double effect. In double effect evaporation, two evaporators are used, and the water vapor from the first evaporator (which may be heated by steam) is used to supply heat to the second evaporator. As it supplies heat, the water vapor from the first evaporator condenses. Approximately equal quantities of wastewater are evaporated in each unit; thus, the double effect system evaporates twice the amount of water that a single effect system does, at nearly the same cost in energy but with added capital cost and complexity. The double effect technique is thermodynamically possible because the second evaporator is maintained at lower pressure (higher vacuum) and, therefore, lower evaporation temperature. Another means of increasing energy efficiency is vapor recompression (thermal or mechanical), which enables heat to be transferred from the condensing water vapor to the evaporating wastewater. Vacuum evaporation equipment may be classified as submerged tube or climbing film evaporation units.

In the most commonly used submerged tube evaporator, the heating and condensing coil are contained in a single vessel to reduce capital cost. The vacuum in the vessel is maintained by an eductor-type pump, which creates the required vacuum by the flow of the condenser cooling water through a venturi. Waste water accumulates in the bottom of the vessel, and it is evaporated by means of submerged steam coils. The resulting water vapor condenses as it contacts the condensing coils in the top of the vessel. The condensate then drips off the condensing coils into a collection trough that carries it out of the vessel. Concentrate is removed from the bottom of the vessel.

The major elements of the climbing film evaporator are the evaporator, separator, condenser, and vacuum pump. Wastewater is "drawn" into the system by the vacuum so that a constant liquid level is maintained in the separator. Liquid enters the steam-jacketed evaporator tubes, and part of it evaporates so that a mixture of vapor and liquid enters the separator. The design of the separator is such that the liquid is continuously circulated from the separator to the evaporator. The vapor entering the separator flows out through a mesh entrainment separator to the condenser, where it is condensed as it flows down through the condenser tubes. The condensate, along with any entrained air, is pumped out of the bottom of the condenser by a liquid ring vacuum pump. The liquid seal provided by the condensate keeps the vacuum in the system from being broken.

Application and Performance. Both atmospheric and vacuum evaporation are used in many industrial plants, mainly for the concentration and recovery of process solutions. Many of these evaporators also recover water for rinsing. Evaporation has also been applied to recovery of phosphate metal cleaning solutions.

In theory, evaporation should yield a concentrate and a deionized condensate. Actually, carry-over has resulted in condensate metal concentrations as high as 10 mg/l, although the usual level is less than 3 mg/l, pure enough for most final rinses. The condensate may also contain organic brighteners and antifoaming agents. These can be removed with an activated carbon bed, if necessary. Samples from one plant showed 1,900 mg/l zinc in the feed, 4,570 mg/l in the concentrate, and 0.4 mg/l in the condensate. Another plant had 416 mg/l copper in the feed and 21,800 mg/l in the concentrate. Chromium analysis for that plant indicated 5,060 mg/l in the feed and 27,500 mg/l in the concentrate. Evaporators are available in a range of capacities, typically from 15 to 75 gph, and may be used in parallel arrangements for processing of higher flow rates.

Advantages and Limitations. Advantages of the evaporation process are that it permits recovery of a wide variety of process chemicals, and it is often applicable to concentration or removal of compounds which cannot be accomplished by any other means. The major disadvantage is that the evaporation process consumes relatively large amounts of energy for the evaporation of water. However, the recovery of waste heat from many industrial processes (e.g., diesel generators, incinerators, boilers and furnaces) should be considered as a source of this heat for a totally integrated evaporation system. Also, in some cases solar heating could be inexpensively and effectively applied to evaporation units. For some applications, pretreatment may be required to remove solids or bacteria which tend to cause fouling in the condenser or evaporator. The buildup of scale on the evaporator surfaces reduces the heat transfer efficiency and may present a maintenance problem or increase operating cost. However, it has been demonstrated that fouling of the heat transfer surfaces can be avoided or minimized for certain dissolved solids by maintaining a seed slurry which provides preferential sites for precipitate deposition. In addition, low temperature differences in the evaporator will eliminate nucleate boiling and supersaturation effects. Steam distillable impurities in the process stream are carried over with the product water and must be handled by pre or post treatment.

Operational Factors. Reliability: Proper maintenance will ensure a high degree of reliability for the system. Without such attention, rapid fouling or deterioration of vacuum seals may occur, especially when handling corrosive liquids.

Maintainability: Operating parameters can be automatically controlled. Pretreatment may be required, as well as periodic cleaning of the system. Regular replacement of seals, especially in a corrosive environment, may be necessary.

Solid Waste Aspects: With only a few exceptions, the process does not generate appreciable quantities of solid waste.

Demonstration Status. Evaporation is a fully developed, commercially available wastewater treatment system. It is used extensively to recover plating chemicals in the electroplating industry and a pilot scale unit has been used in connection with phosphating of aluminum. Proven performance in silver recovery indicates that evaporation could be a useful treatment operation for the photographic industry, as well as for metal finishing.

18. Gravity Sludge Thickening

In the gravity thickening process, dilute sludge is fed from a primary settling tank or clarifier to a thickening tank where rakes stir the sludge gently to densify it and to push it to a central collection well. The supernatant is returned to the primary settling tank. The thickened sludge that collects on the bottom of the tank is pumped to dewatering equipment or hauled away. Figure VII-24 (page 217) shows the construction of a gravity thickener.

Application and Performance. Thickeners are generally used in facilities where the sludge is to be further dewatered by a compact mechanical device such as a vacuum filter or centrifuge. Doubling the solids content in the thickener substantially reduces capital and operating cost of the subsequent dewatering device and also reduces cost for hauling. The process is potentially applicable to almost any industrial plant.

Organic sludges from sedimentation units of one to two percent solids concentration can usually be gravity thickened to six to ten percent; chemical sludges can be thickened to four to six percent.

Advantages and Limitations. The principal advantage of a gravity sludge thickening process is that it facilitates further sludge dewatering. Other advantages are high reliability and minimum maintenance requirements.

Limitations of the sludge thickening process are its sensitivity to the flow rate through the thickener and the sludge removal rate. These rates must be low enough not to disturb the thickened sludge.

Operational Factors. Reliability: Reliability is high with proper design and operation. A gravity thickener is designed on the basis of square feet per pound of solids per day, in which the required surface area is related to the solids entering and leaving the unit. Thickener area requirements are also expressed in terms of mass loading, grams of solids per square meter per day (lbs/sq ft/day).

Maintainability: Twice a year, a thickener must be shut down for lubrication of the drive mechanisms. Occasionally, water must be pumped back through the system in order to clear sludge pipes.

Solid Waste Aspects: Thickened sludge from a gravity thickening process will usually require further dewatering prior to disposal, incineration, or drying. The clear effluent may be recirculated in part, or it may be subjected to further treatment prior to discharge.

Demonstration Status. Gravity sludge thickeners are used throughout industry to reduce water content to a level where the sludge may be efficiently handled. Further dewatering is usually practiced to minimize costs of hauling the sludge to approved landfill areas. Sludge thickening is used in seven coil coating plants.

19. Insoluble Starch Xanthate

Insoluble starch xanthate is essentially an ion exchange medium used to remove dissolved heavy metals from wastewater. The water may then either be reused (recovery application) or discharged (end-of-pipe application). In a commercial electroplating operation, starch xanthate is coated on a filter medium. Rinse water containing dragged out heavy metals is circulated through the filters and then reused for rinsing. The starch-heavy metal complex is disposed of and replaced periodically. Laboratory tests indicate that recovery of metals from the complex is feasible, with regeneration of the starch xanthate. Besides electroplating, starch xanthate is potentially applicable to coil coating, porcelain enameling, copper fabrication, and any other industrial plants where dilute metal wastewater streams are generated. Its present use is limited to one electroplating plant.

20. Ion Exchange

Ion exchange is a process in which ions, held by electrostatic forces to charged functional groups on the surface of the ion exchange resin, are exchanged for ions of similar charge from the solution in which the resin is immersed. This is classified as a sorption process because the exchange occurs on the surface of the resin, and the exchanging ion must undergo a phase transfer from solution phase to solid phase. Thus, ionic contaminants in a waste stream can be exchanged for the harmless ions of the resin.

Although the precise technique may vary slightly according to the application involved, a generalized process description follows. The wastewater stream being treated passes through a filter to remove any solids, then flows through a cation exchanger which contains the ion exchange resin. Here, metallic impurities such as copper, iron, and trivalent chromium are retained. The stream then passes through the anion exchanger and its associated resin. Hexavalent chromium, for example, is retained in this stage. If one pass does not reduce the contaminant levels sufficiently, the stream may then enter another series of exchangers. Many ion exchange systems are equipped with more than one set of exchangers for this reason.

The other major portion of the ion exchange process concerns the regeneration of the resin, which now holds those impurities retained from the waste stream. An ion exchange unit with in-place regeneration is shown in Figure VII-25 (page 218). Metal ions such as nickel are removed by an acid, cation exchange resin, which is regenerated with hydrochloric or sulfuric acid, replacing the metal ion with one or more hydrogen ions. Anions such as dichromate are removed by a basic, anion exchange resin, which is regenerated with sodium hydroxide, replacing the anion with one or more hydroxyl ions. The three principal methods employed by industry for regenerating the spent resin are:

A) Replacement Service: A regeneration service replaces the spent resin with regenerated resin, and regenerates the spent resin at its own facility. The service then has the problem of treating and disposing of the spent regenerant.

B) In-Place Regeneration: Some establishments may find it less expensive to do their own regeneration. The spent resin column is shut down for perhaps an hour, and the spent resin is regenerated. This results in one or more waste streams which must be treated in an appropriate manner. Regeneration is performed as the resins require it, usually every few months.

C) Cyclic Regeneration: In this process, the regeneration of the spent resins takes place within the ion exchange unit itself in alternating cycles with the ion removal process. A regeneration frequency of twice an hour is typical. This very short cycle time permits operation with a very small quantity of resin and with fairly concentrated solutions, resulting in a very compact system. Again, this process varies according to application, but the regeneration cycle generally begins with caustic being pumped through the anion exchanger, carrying out hexavalent chromium, for example, as sodium dichromate. The sodium dichromate stream then passes through a cation exchanger, converting the sodium dichromate to chromic acid. After concentration by evaporation or other means, the chromic acid can be returned to the process line. Meanwhile, the cation exchanger is regenerated with sulfuric acid, resulting in a waste acid stream containing the metallic impurities removed earlier. Flushing the exchangers with water completes the cycle. Thus, the wastewater is purified and, in this example, chromic acid is recovered. The ion exchangers, with newly regenerated resin, then enter the ion removal cycle again.

Application and Performance. The list of pollutants for which the ion exchange system has proven effective includes aluminum, arsenic, cadmium, chromium (hexavalent and trivalent), copper, cyanide, gold, iron, lead, manganese, nickel, selenium, silver, tin, zinc, and more. Thus, it can be applied to a wide variety of industrial concerns. Because of the heavy concentrations of metals in their wastewater, the metal finishing industries utilize ion exchange in several ways. As an end-of-pipe treatment, ion exchange is certainly feasible, but its greatest value is in recovery applications. It is commonly used as an integrated treatment to recover rinse water and process chemicals. Some electroplating facilities use ion exchange to concentrate and purify plating baths. Also, many industrial concerns, including a number of coil coating plants, use ion exchange to reduce salt concentrations in incoming water sources.

Ion exchange is highly efficient at recovering metal bearing solutions. Recovery of chromium, nickel, phosphate solution, and sulfuric acid from anodizing is commercial. A chromic acid recovery efficiency of 99.5 percent has been demonstrated. Typical data for purification of rinse water have been reported and are displayed in Table VII-25 (page 190).

Ion exchange is a versatile technology applicable to a great many situations. This flexibility, along with its compact nature and performance, makes ion exchange a very effective method of waste water treatment. However, the resins in these systems can prove to be a limiting factor. The thermal limits of the anion resins, generally in the vicinity of 60°C, could prevent its use in certain situations. Similarly, nitric acid, chromic acid, and hydrogen peroxide can all damage the resins, as will iron, manganese, and copper when present with sufficient concentrations of dissolved oxygen. Removal of a particular trace contaminant may be uneconomical because of the presence of other ionic species that are preferentially removed. The regeneration of the resins presents its own problems. The cost of the regenerative chemicals can be high. In addition, the waste streams originating from the regeneration process are extremely high in pollutant concentrations, although low in volume. These must be further processed for proper disposal.

Operational Factors. Reliability: With the exception of occasional clogging or fouling of the resins, ion exchange has proved to be a highly dependable technology.

Maintainability: Only the normal maintenance of pumps, valves, piping and other hardware used in the regeneration process is required.

Solid Waste Aspects: Few, if any, solids accumulate within the ion exchangers, and those which do appear are removed by the regeneration process. Proper prior treatment and planning can eliminate solid buildup problems altogether. The brine resulting from regeneration of the ion exchange resin most usually must be treated to remove metals before discharge. This can generate solid waste.

Demonstration Status. All of the applications mentioned in this document are available for commercial use, and industry sources estimate the number of units currently in the field at well over 120. The research and development in ion exchange is focusing on improving the quality and efficiency of the resins, rather than new applications. Work is also being done on a continuous regeneration process whereby the resins are contained on a fluid-transfusible belt. The belt passes through a compartmented tank with ion exchange, washing, and regeneration sections. The resins are therefore continually used and regenerated. No such system, however, has been reported beyond the pilot stage.

21. Membrane Filtration

Membrane filtration is a treatment system for removing precipitated metals from a wastewater stream. It must therefore be preceded by those treatment techniques which will properly prepare the wastewater for solids removal. Typically, a membrane filtration unit is preceded by pH adjustment or sulfide addition for precipitation of the metals. These steps are followed by the addition of a proprietary chemical reagent which causes the precipitate to be non-gelatinous, easily dewatered, and highly stable. The resulting mixture of pretreated wastewater and reagent is continuously recirculated through a filter module and back into a recirculation tank. The filter module contains tubular membranes. While the reagent-metal hydroxide precipitate mixture flows through the inside of the tubes, the water and any dissolved salts permeate the membrane. When the recirculating slurry reaches a concentration of 10 to 15 percent solids, it is pumped out of the system as sludge.

Application and Performance. Membrane filtration appears to be applicable to any wastewater or process water containing metal ions which can be precipitated using hydroxide, sulfide or carbonate precipitation. It could function as the primary treatment system, but also might find application as a polishing treatment (after precipitation and settling) to ensure continued compliance with metals limitations. Membrane filtration systems are being used in a number of industrial applications, particularly in the metal finishing area. They have also been used for heavy metals removal in the metal fabrication industry and the paper industry.

The permeate is claimed by one manufacturer to contain less than the effluent concentrations shown in the following table, regardless of the influent concentrations. These claims have been largely substantiated by the analysis of water samples at various plants in various industries.

In the performance predictions for this technology, pollutant concentrations are reduced to the levels shown in Table VII-26 (page 191) unless lower levels are present in the influent stream.

A major advantage of the membrane filtration system is that installations can use most of the conventional end-of-pipe systems that may already be in place. Removal efficiencies are claimed to be excellent, even with sudden variation of pollutant input rates; however, the effectiveness of the membrane filtration system can be limited by clogging of the filters. Because pH changes in the waste stream greatly intensify clogging problems, the pH must be carefully monitored and controlled. Clogging can force the shutdown of the system and may interfere with production. In addition, relatively high capital cost of this system may limit its use.

Operational Factors. Reliability: Membrane filtration has been shown to be a very reliable system, provided that the pH is strictly controlled. Improper pH can result in the clogging of the membrane. Also, surges in the flow rate of the waste stream must be controlled in order to prevent solids from passing through the filter and into the effluent.

Maintainability: The membrane filters must be regularly monitored, and cleaned or replaced as necessary. Depending on the composition of the waste stream and its flow rate, frequent cleaning of the filters may be required. Flushing with hydrochloric acid for 6-24 hours will usually suffice. In addition, the routine maintenance of pumps, valves, and other plumbing is required.

Solid Waste Aspects: When the recirculating reagent-precipitate slurry reaches 10 to 15 percent solids, it is pumped out of the system. It can then be disposed of directly or it can undergo a dewatering process. Because this sludge contains toxic metals, it requires proper disposal.

Demonstration Status. There are more than 25 membrane filtration systems presently in use on metal finishing and similar wastewaters. Bench scale and pilot studies are being run in an attempt to expand the list of pollutants for which this system is known to be effective. A unit has been installed at one coil coating plant based on these tests.

22. Peat Adsorption

Peat moss is a complex natural organic material containing lignin and cellulose as major constituents. These constituents, particularly lignin, bear polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers, that can be involved in chemical bonding. Because of the polar nature of the material, its adsorption of dissolved solids such as transition metals and polar organic molecules is quite high. These properties have led to the use of peat as an agent for the purification of industrial wastewater.

Peat adsorption is a "polishing" process which can achieve very low effluent concentrations for several pollutants. If the concentrations of pollutants are above 10 mg/l, then peat adsorption must be preceded by pH adjustment for metals precipitation and subsequent clarification. Pretreatment is also required for chromium wastes using ferric chloride and sodium sulfide. The wastewater is then pumped into a large metal chamber called a kier which contains a layer of peat through which the waste stream passes. The water flows to a second kier for further adsorption. The wastewater is then ready for discharge. This system may be automated or manually operated.

Application and Performance. Peat adsorption can be used for removal of residual dissolved metals from clarifier effluent. Peat moss may be used to treat wastewaters containing heavy metals such as mercury, cadmium, zinc, copper, iron, nickel, chromium, and lead, as well as organic matter such as oil, detergents, and dyes. Peat adsorption is currently used commercially at a textile plant, a newsprint facility, and a metal reclamation operation.

Table VII-27 (page 191) contains performance figures obtained from pilot plant studies. Peat adsorption was preceded by pH adjustment for precipitation and by clarification.

In addition, pilot plant studies have shown that chelated metal wastes, as well as the chelating agents themselves, are removed by contact with peat moss.

Advantages and Limitations. The major advantages of the system include its ability to yield low pollutant concentrations, its broad scope in terms of the pollutants eliminated, and its capacity to accept wide variations of waste water composition.

Limitations include the cost of purchasing, storing, and disposing of the peat moss; the necessity for regular replacement of the peat may lead to high operation and maintenance costs. Also, the pH adjustment must be altered according to the composition of the waste stream.

Operational Factors. Reliability: The question of long term reliability is not yet fully answered. Although the manufacturer reports it to be a highly reliable system, operating experience is needed to verify the claim.

Maintainability: The peat moss used in this process soon exhausts its capacity to adsorb pollutants. At that time, the kiers must be opened, the peat removed, and fresh peat placed inside. Although this procedure is easily and quickly accomplished, it must be done at regular intervals, or the system's efficiency drops drastically.

Solid Waste Aspects: After removal from the kier, the spent peat must be eliminated. If incineration is used, precautions should be taken to insure that those pollutants removed from the water are not released again in the combustion process. Presence of sulfides in the spent peat, for example, will give rise to sulfur dioxide in the fumes from burning. The presence of significant quantities of toxic heavy metals in canmaking wastewater will in general preclude incineration of peat used in treating these wastes.

Demonstration Status. Only three facilities currently use commercial adsorption systems in the United States - a textile manufacturer, a newsprint facility, and a metal reclamation firm.

23. Reverse Osmosis

The process of osmosis involves the passage of a liquid through a semipermeable membrane from a dilute to a more concentrated solution. Reverse osmosis (RO) is an operation in which pressure is applied to the more concentrated solution, forcing the permeate to diffuse through the membrane and into the more dilute solution. This filtering action produces a concentrate and a permeate on opposite sides of the membrane. The concentrate can then be further treated or returned to the original operation for continued use, while the permeate water can be recycled for use as clean water. Figure VII-26 (page 219) depicts a reverse osmosis system.

As illustrated in Figure VII-27 (page 220), there are three basic configurations used in commercially available RO modules: tubular, spiral-wound, and hollow fiber. All of these operate on the principle described above, the major difference being their mechanical and structural design characteristics.

The tubular membrane module uses a porous tube with a cellulose acetate membrane-lining. A common tubular module consists of a length of 2.5 cm (1 inch) diameter tube wound on a supporting spool and encased in a plastic shroud. Feed water is driven into the tube under pressures varying from 40 - 55 atm (600-800 psi). The permeate passes through the walls of the tube and is collected in a manifold while the concentrate is drained off at the end of the tube. A less widely used tubular RO module uses a straight tube contained in a housing, under the same operating conditions.

Spiral-wound membranes consist of a porous backing sandwiched between two cellulose acetate membrane sheets and bonded along three edges. The fourth edge of the composite sheet is attached to a large permeate collector tube. A spacer screen is then placed on top of the membrane sandwich and the entire stack is rolled around the centrally located tubular permeate collector. The rolled up package is inserted into a pipe able to withstand the high operating pressures employed in this process, up to 55 atm (800 psi) with the spiral-wound module. When the system is operating, the pressurized product water permeates the membrane and flows through the backing material to the central collector tube. The concentrate is drained off at the end of the container pipe and can be reprocessed or sent to further treatment facilities.

The hollow fiber membrane configuration is made up of a bundle of polyamide fibers of approximately 0.0075 cm (0.003 in.) OD and 0.0043 cm (0.0017 in.) ID. A commonly used hollow fiber module contains several hundred thousand of the fibers placed in a long tube, wrapped around a flow screen, and rolled into a spiral. The fibers are bent in a U-shape and their ends are supported by an epoxy bond. The hollow fiber unit is operated under 27 atm (400 psi), the feed water being dispersed from the center of the module through a porous distributor tube. Permeate flows through the membrane to the hollow interiors of the fibers and is collected at the ends of the fibers.

The hollow fiber and spiral-wound modules have a distinct advantage over the tubular system in that they are able to load a very large membrane surface area into a relatively small volume. However, these two membrane types are much more susceptible to fouling than the tubular system, which has a larger flow channel. This characteristic also makes the tubular membrane much easier to clean and regenerate than either the spiral-wound or hollow fiber modules. One manufacturer claims that their helical tubular module can be physically wiped clean by passing a soft porous polyurethane plug under pressure through the module.

Application and Performance. In a number of metal processing plants, the overflow from the first rinse in a countercurrent setup is directed to a reverse osmosis unit, where it is separated into two streams. The concentrated stream contains dragged out chemicals and is returned to the bath to replace the loss of solution due to evaporation and dragout. The dilute stream (the permeate) is routed to the last rinse tank to provide water for the rinsing operation. The rinse flows from the last tank to the first tank and the cycle is complete.

The closed-loop system described above may be supplemented by the addition of a vacuum evaporator after the RO unit in order to further reduce the volume of reverse osmosis concentrate. The evaporated vapor can be condensed and returned to the last rinse tank or sent on for further treatment.

The largest application has been for the recovery of nickel solutions. It has been shown that RO can generally be applied to most acid metal baths with a high degree of performance, providing that the membrane unit is not overtaxed. The limitations most critical here are the allowable pH range and maximum operating pressure for each particular configuration. Adequate prefiltration is also essential. Only three membrane types are readily available in commercial RO units, and their overwhelming use has been for the recovery of various acid metal baths. For the purpose of calculating performance predictions of this technology, a rejection ratio of 98 percent is assumed for dissolved salts, with 95 percent permeate recovery.

Advantages and Limitations. The major advantage of reverse osmosis for handling process effluents is its ability to concentrate dilute solutions for recovery of salts and chemicals with low power requirements. No latent heat of vaporization or fusion is required for effecting separations; the main energy requirement is for a high pressure pump. It requires relatively little floor space for compact, high capacity units, and it exhibits good recovery and rejection rates for a number of typical process solutions. A limitation of the reverse osmosis process for treatment of process effluents is its limited temperature range for satisfactory operation. For cellulose acetate systems, the preferred limits are 18° to 30°C (65° to 85°F); higher temperatures will increase the rate of membrane hydrolysis and reduce system life, while lower temperatures will result in decreased fluxes with no damage to the membrane. Another limitation is inability to handle certain solutions. Strong oxidizing agents, strongly acidic or basic solutions, solvents, and other organic compounds can cause dissolution of the membrane. Poor rejection of some compounds such as borates and low molecular weight organics is another problem. Fouling of membranes by slightly soluble components in solution or colloids has caused failures, and fouling of membranes by feed waters with high levels of suspended solids can be a problem. A final limitation is inability to treat or achieve high concentration with some solutions. Some concentrated solutions may have initial osmotic pressures which are so high that they either exceed available operating pressures or are uneconomical to treat.

Operational Factors. Reliability: Very good reliability is achieved so long as the proper precautions are taken to minimize the chances of fouling or degrading the membrane. Sufficient testing of the waste stream prior to application of an RO system will provide the information needed to insure a successful application.

Maintainability: Membrane life is estimated to range from six months to three years, depending on the use of the system. Down time for flushing or cleaning is on the order of 2 hours as often as once each week; a substantial portion of maintenance time must be spent on cleaning any prefilters installed ahead of the reverse osmosis unit.

Solid Waste Aspects: In a closed loop system utilizing RO there is a constant recycle of concentrate and a minimal amount of solid waste. Prefiltration eliminates many solids before they reach the module and helps keep the buildup to a minimum. These solids require proper disposal.

Demonstration Status. There are presently at least one hundred reverse osmosis waste water applications in a variety of industries. In addition to these, there are thirty to forty units being used to provide pure process water for several industries. Despite the many types and configurations of membranes, only the spiral-wound cellulose acetate membrane has had widespread success in commercial applications. One canmaking plant has reverse osmosis equipment in-place.

24. Sludge Bed Drying

As a waste treatment procedure, sludge bed drying is employed to reduce the water content of a variety of sludges to the point where they are amenable to mechanical collection and removal to landfill. These beds usually consist of 15 to 45 cm (6 to 18 in.) of sand over a 30 cm (12 in.) deep gravel drain system made up of 3 to 6 mm (1/8 to 1/4 in.) graded gravel overlying drain tiles. Figure VII-28 (page 221) shows the construction of a drying bed.

Drying beds are usually divided into sectional areas approximately 7.5 meters (25 ft) wide x 30 to 60 meters (100 to 200 ft) long. The partitions may be earth embankments, but more often are made of planks and supporting grooved posts.

To apply liquid sludge to the sand bed, a closed conduit or a pressure pipeline with valved outlets at each sand bed section is often employed. Another method of application is by means of an open channel with appropriately placed side openings which are controlled by slide gates. With either type of delivery system, a concrete splash slab should be provided to receive the falling sludge and prevent erosion of the sand surface.

Where it is necessary to dewater sludge continuously throughout the year regardless of the weather, sludge beds may be covered with a fiberglass reinforced plastic or other roof. Covered drying beds permit a greater volume of sludge drying per year in most climates because of the protection afforded from rain or snow and because of more efficient control of temperature. Depending on the climate, a combination of open and enclosed beds will provide maximum utilization of the sludge bed drying facilities.

Application and Performance. Sludge drying beds are a means of dewatering sludge from clarifiers and thickeners. They are widely used both in municipal and industrial treatment facilities.

Dewatering of sludge on sand beds occurs by two mechanisms: filtration of water through the bed and evaporation of water as a result of radiation and convection. Filtration is generally complete in one to two days and may result in solids concentrations as high as 15 to 20 percent. The rate of filtration depends on the drainability of the sludge.

The rate of air drying of sludge is related to temperature, relative humidity, and air velocity. Evaporation will proceed at a constant rate to a critical moisture content, then at a falling rate to an equilibrium moisture content. The average evaporation rate for a sludge is about 75 percent of that from a free water surface.

Advantages and Limitations. The main advantage of sludge drying beds over other types of sludge dewatering is the relatively low cost of construction, operation, and maintenance.

Its disadvantages are the large area of land required and long drying times that depend, to a great extent, on climate and weather.

Operational Factors. Reliability: Reliability is high with favorable climactic conditions, proper bed design and care to avoid excessive or unequal sludge application. If climatic conditions in a given area are not favorable for adequate drying, a cover may be necessary.

Maintainability: Maintenance consists basically of periodic removal of the dried sludge. Sand removed from the drying bed with the sludge must be replaced and the sand layer resurfaced.

The resurfacing of sludge beds is the major expense item in sludge bed maintenance, but there are other areas which may require attention. Underdrains occasionally become clogged and have to be cleaned. Valves or sludge gates that control the flow of sludge to the beds must be kept watertight. Provision for drainage of lines in winter should be provided to prevent damage from freezing. The partitions between beds should be tight so that sludge will not flow from one compartment to another. The outer walls or banks around the beds should also be watertight.

Solid Waste Aspects: The full sludge drying bed must either be abandoned or the collected solids must be removed to a landfill. These solids contain whatever metals or other materials were settled in the clarifier. Metals will be present as hydroxides, oxides, sulfides, or other salts. They have the potential for leaching and contaminating ground water, whatever the location of the semidried solids. Thus the abandoned bed or landfill should include provision for runoff control and leachate monitoring.

Demonstration Status. Sludge beds have been in common use in both municipal and industrial facilities for many years. However, protection of ground water from contamination is not always adequate.

25. Ultrafiltration

Ultrafiltration (UF) is a process which uses semipermeable polymeric membranes to separate emulsified or colloidal materials suspended in a liquid phase by pressurizing the liquid so that it permeates the membrane. The membrane of an ultrafilter forms a molecular screen which retains molecular particles based on their differences in size, shape, and chemical structure. The membrane permits passage of solvents and lower molecular weight molecules. At present, an ultrafilter is capable of removing materials with molecular weights in the range of 1,000 to 100,000 and particles of comparable or larger sizes.

In an ultrafiltration process, the feed solution is pumped through a tubular membrane unit. Water and some low molecular weight materials pass through the membrane under the applied pressure of 10 to 100 psig. Emulsified oil droplets and suspended particles are retained, concentrated, and removed continuously. In contrast to ordinary filtration, retained materials are washed off the membrane filter rather than held by it. Figure VII-29 (page 192) represents the ultrafiltration process.

Application and Performance. Ultrafiltration has potential application to canmaking plants for separation of oils and residual solids from a variety of waste streams. In treating canmaking wastewater its greatest applicability would be as a polishing treatment to remove residual precipitated metals after chemical precipitation and clarification. Successful commercial use, however, has been primarily for separation of emulsified oils from wastewater. Over one hundred such units now operate in the United States, treating emulsified oils from a variety of industrial processes. Capacities of currently operating units range from a few hundred gallons a week to 50,000 gallons per day. Concentration of oily emulsions to 60 percent oil or more are possible. Oil concentrates of 40 percent or more are generally suitable for incineration, and the permeate can be treated further and in some cases recycled back to the process. In this way, it is possible to eliminate contractor removal costs for oil from some oily waste streams.

Table VII-28 (page 191) indicates ultrafiltration performance (note that UF is not intended to remove dissolved solids):

The removal percentages shown are typical, but they can be influenced by pH and other conditions. The high TSS level is unusual for this technology and ultrafiltration is assumed to reduce the TSS level by one-thrid after mixed media filtration.

The permeate or effluent from the ultrafiltration unit is normally of a quality that can be reused in industrial applications or discharged directly. The concentrate from the ultrafiltration unit can be disposed of as any oily or solid waste.

Advantages and Limitations. Ultrafiltration is sometimes an attractive alternative to chemical treatment because of lower capital equipment, installation, and operating costs, very high oil and suspended solids removal, and little required pretreatment. It places a positive barrier between pollutants and effluent which reduces the possibility of extensive pollutant discharge due to operator error or upset in settling and skimming systems. Alkaline values in alkaline cleaning solutions can be recovered and reused in process.

A limitation of ultrafiltration for treatment of process effluents is its narrow temperature range (18° to 30°C) for satisfactory operation. Membrane life decreases with higher temperatures, but flux increases at elevated temperatures. Therefore, surface area requirements are a function of temperature and become a tradeoff between initial costs and replacement costs for the membrane. In addition, ultrafiltration cannot handle certain solutions. Strong oxidizing agents, solvents, and other organic compounds can dissolve the membrane. Fouling is sometimes a problem, although the high velocity of the wastewater normally creates enough turbulence to keep fouling at a minimum. Large solids particles can sometimes puncture the membrane and must be removed by gravity settling or filtration prior to the ultrafiltration unit.

Operational Factors. Reliability: The reliability of an ultrafiltration system is dependent on the proper filtration, settling or other treatment of incoming waste streams to prevent damage to the membrane. Careful pilot studies should be done in each instance to determine necessary pretreatment steps and the exact membrane type to be used.

Maintainability: A limited amount of regular maintenance is required for the pumping system. In addition, membranes must be periodically changed. Maintenance associated with membrane plugging can be reduced by selection of a membrane with optimum physical characteristics and sufficient velocity of the waste stream. It is often necessary to occasionally pass a detergent solution through the system to remove an oil and grease film which accumulates on the membrane. With proper maintenance membrane life can be greater than twelve months.

Solid Waste Aspects: Ultrafiltration is used primarily to recover solids and liquids. It therefore eliminates solid waste problems when the solids (e.g., paint solids) can be recycled to the process. Otherwise, the stream containing solids must be treated by end-of-pipe equipment. In the most probable applications within the coil coating category, the ultrafilter would remove hydroxides or sulfides of metals which have recovery value.

Demonstration Status. The ultrafiltration process is well developed and commercially available for treatment of wastewater or recovery of certain high molecular weight liquid and solid contaminants. One canmaking plant has ultrafiltration equipment in-place.

26. Vacuum Filtration

In wastewater treatment plants, sludge dewatering by vacuum filtration generally uses cylindrical drum filters. These drums have a filter medium which may be cloth made of natural or synthetic fibers or a wire-mesh fabric. The drum is suspended above and dips into a vat of sludge. As the drum rotates slowly, part of its circumference is subject to an internal vacuum that draws sludge to the filter medium. Water is drawn through the porous filter cake to a discharge port, and the dewatered sludge, loosened by compressed air, is scraped from the filter mesh. Because the dewatering of sludge on vacuum filters is relativley expensive per kilogram of water removed, the liquid sludge is frequently thickened prior to processing. A vacuum filter is shown in Figure VII-30 (page 223).

Application and Performance. Vacuum filters are frequently used both in municipal treatment plants and in a wide variety of industries. They are most commonly used in larger facilities, which may have a thickener to double the solids content of clarifier sludge before vacuum filtering.

The function of vacuum filtration is to reduce the water content of sludge, so that the solids content increases from about 5 percent to about 30 percent.

Advantages and Limitations. Although the initial cost and area requirement of the vacuum filtration system are higher than those of a centrifuge, the operating cost is lower, and no special provisions for sound and vibration protection need be made. The dewatered sludge from this process is in the form of a moist cake and can be conveniently handled.

Operational Factors. Reliability: Vacuum filter systems have proven reliable at many industrial and municipal treatment facilities. At present, the largest municipal installation is at the West Southwest wastewater treatment plant of Chicago, Illinois, where 96 large filters were installed in 1925, functioned approximately 25 years, and then were replaced with larger units. Original vacuum filters at Minneapolis-St. Paul, Minnesota now have over 28 years of continuous service, and Chicago has some units with similar or greater service life.

Maintainability: Maintenance consists of the cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the equipment. Experience in a number of vacuum filter plants indicates that maintenance consumes approximately 5 to 15 percent of the total time. If carbonate buildup or other problems are unusually severe, maintenance time may be as high as 20 percent. For this reason, it is desirable to maintain one or more spare units.

Demonstration Status. Vacuum filtration has been widely used for many years. It is a fully proven, conventional technology for sludge dewatering.

IN-PLANT TECHNOLOGY

The intent of in-plant technology for the canmaking subcategory of the coil coating point source category is to reduce or eliminate the waste load requiring end-of-pipe treatment and thereby improve the efficiency of an existing wastewater treatment system or reduce the requirements of a new treatment system. In-plant technology involves improved rinsing, water conservation, process bath conservation, reduction of dragout, automatic controls, good housekeeping practices, recovery and reuse of process solutions, process modification and waste treatment. The in-plant technology has been divided into two areas:

- In-process treatment and controls
- Process substitutions

In-Process Treatment and Controls

In-process treatment and controls can apply to both existing and new installations and use technologies and methodologies that have already been developed. The reduction in chemical and water usage are desirable because of the attendant reductions in pollutant discharge which results from treating smaller volumes of more concentrated waste streams.

A major portion of the oil, grease, dirt and oxide coating is removed from the can by cleaning and rinsing. Cleaning of the can is extremely important because incomplete cleaning adversely affects subsequent operations. The primary factors that adversely affect cleaning and rinsing efficiency are:

- Incorrect cleaning compound for basis material.
- Incorrect temperature of cleaning solution and rinse water.
- Insufficient number of spray nozzles or insufficient pressure for both cleaning and rinsing.
- Absence of bath equilibrium controls that automatically add make-up water and cleaning solution.
- Undefined soils
- Insufficient time

Cleaning solutions are formulated for specific basis materials. The most advanced cleaning solutions contain phosphates that form soluble complexes with the dissolved basis materials rather than an insoluble sludge. The formation of an insoluble sludge may necessitate discarding the solution before exhausting all available alkalinity.

Operating temperature is as important as the proper cleaning solution and concentration. A solution that is too cold may not be able to dissolve either enough of the cleaning compound or the oils from the can. Excessive temperature may cause excessive foaming.

Spray nozzles and pressures should be adequate to assure overlapping coverage of the work area. Experience will dictate how fast the line can move and be effectively cleaned with a given set of spray nozzles and pressure.

The use of cleaning rinse water as make-up to the cleaning tank can conserve water. Another applicable water conservation mechanism (particularly for new installations) is a countercurrent rinse. Multi-stage and countercurrent rinses are employed at many industrial plants. In many cases, however, these techniques are not combined with effective flow control, and the wastewater discharge volumes from the multi-stage or countercurrent rinses are as large as or larger than corresponding single stage rinse flows at other plants. Countercurrent rinsing is more efficient than multiple single stage rinses from the standpoint of water use. In countercurrent rinsing one fresh water feed is used for the last tank in the production sequence. The overflow from each tank in the production sequence becomes the feed for the tank preceeding it; the water flow from tank to tank cascades countercurrently to the products sequence.

Countercurrent Cascade Rinsing

Rinse water requirements and the benefits of countercurrent rinsing may be influenced by the volume of solution dragout carried into each rinse stage by the material being rinsed, by the number of rinse stages used, by the initial concentrations of impurities being removed, and by the final product cleanliness required (see Figures III-3 and III-4). The influence of these factors is expressed in the rinsing equation which may be stated simply as:

$$V\underline{r} = \{C\underline{o}/C\underline{f}\}^{1/n} \times V\underline{d}$$

$V\underline{r}$ is the flow through each rinse stage.
$C\underline{o}$ is the concentration of the contaminant(s) in the initial process bath

$C\underline{f}$ is the concentration of the contaminant(s) in the final rinse to give acceptable product cleanliness.
n is the number of rinse stages employed

and

$V\underline{d}$ is the drag-out carried into each rinse stage, expressed as a flow.

For convenience we can set r = $C\underline{o}/C\underline{f}$ because for any set of calculations about flow reduction, the cleanliness ratio $C\underline{o}/C\underline{f}$ is the same. For a multi-stage rinse, the total volume of rinse wastewater is equal to n times $V\underline{r}$, while for a countercurrent rinse the total volume of wastewater discharge equals $V\underline{r}$.

Drag-out is solution which remains on the surface of material being rinsed when the surface is transferred from process baths or rinses.

To calculate the cleanliness ratio, r, we start with BPT water use of 176.7 l/1000 cans and subtract a 10 percent allowance for wastewater generated from oil sump discharge, ion exchange regeneration, fume scrubber discharge, and batch dumps of process tanks (i.e. acid cleaner and conversion coating solution). Thus, 176.7 - 17.7 = 159.0 l/1000 cans represents the rinse water use for single stage rinses.

Without specific data available to determine drag-out we can assume a dragout film thickness of 0.075 mm (2.9 mils) which is equivalent to a poorly drained vertical surface film thickness; and a surface area of 555 sq. cm for a standard 12 ounce can body (can diameter is 6.5 cm and can height is 12.0 cm). The volume of dragout or carryover is:

V_d = 555 sq cm/can x .0075 cm = 4.16 cu cm/can (ml/can) or 4.16 l/1000 cans

Given the configuration of the inverted seamless can body as it passes through the washer with a dished impression in the bottom, 4.16 ml per can carryover from one stage to the next by an inverted can which has little time to drain, seems reasonable especially when an air knife is used. Substituting in the rinsing equation for a single stage rinse, $V_r = r \times V_d$, and solving for r, we get

$$r = \frac{159}{4.16} = 38.22.$$

If a two stage countercurrent spray rinse is substituted for the single stage rinse, we get for a rinse water volume:

$$\begin{aligned} V_r &= (38.22)^{1/2}\,(4.16) \\ &= 6.18 \times 4.16 \\ &= 25.7 \text{ l/1000 cans} \end{aligned}$$

If a three stage countercurrent spray rinse is substituted for the single stage rinse, we get for a rinse water volume:

$$\begin{aligned} V_r &= (38.22)^{1/3}\,(4.16) \\ &= 3.368 \times 4.16 \\ &= 14.01 \text{ l/1000 cans} \end{aligned}$$

In-process Control

The conversion coating function is a key step of the canmaking operation. This is one of the steps in which material is added to the can. The two types of conversion coating used on cans are chromating and phosphating.

A number of parameters require monitoring and control to maximize coating formation rate and minimize the amount of material discarded.

All types of conversion coating operations require careful monitoring and control of pH. If the pH is not kept at the optimum level, either the chemical reaction proceeds too slowly or the surface of the can is excessively etched. The pH of the system can be sensed electronically and automatic make-up of specific chemicals performed in accordance with manufacturers' specifications. Chemical suppliers provide a series of chemicals for each type of conversion coating. The series includes a new bath formulation and one or two replenishment chemicals depending upon the constituent that has been depleted. This system maximizes use of all chemicals and provides for a continued high quality product.

Temperature must be constantly monitored and kept within an acceptable range. Low temperatures will slow film formation and high temperatures will degrade the freshly formed film. For a given line speed, there should be adequate spray nozzle coverage and pressure. This assures that all areas of each can have sufficient reaction time to allow buildup of a specified film thickness.

The chromating conversion coating chemicals contain significant quantities of hexavalent and trivalent chromium. The hexavalent chromium eventually becomes reduced to trivalent chromium, precluding its use as part of the film. Certain chromating conversion coating systems are designed to regenerate chromium. These systems pump chromating conversion coating solution out of the process tank to another tank where it is electrolytically regenerated. This application of electrical current to the solution increases the valence of the trivalent chromium to hexavalent chromium. The solution is then returned to the process tank.

In-Process Substitutions

The in-process substitutions for this industry involve only the conversion coating phases of the total operation. The cleaning, rinsing, and painting remain virtually unchanged. These in-process substitutions eliminate the discharge of a significant pollutant from the conversion coating operation.

Certain chromating solutions contain cyanide ions to promote faster reaction of the solution. Cyanide is a priority pollutant which requires separate treatment to remove it once it is in solution.

There are competing chemical systems that do not contain cyanide and efforts should be made to eliminate cyanide use where possible.

TABLE VII-1
pH CONTROL EFFECT ON METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	2.4-3.4	8.5-8.7	1.0-3.0	5.0-6.0	2.0-5.0	6.5-8.1
(mg/l)						
TSS	39	8	16	19	16	7
Copper	312	0.22	120	5.12	107	0.66
Zinc	250	0.31	32.5	25.0	43.8	0.66

TABLE VII-2

Effectiveness of Sodium Hydroxide for Metals Removal

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range (mg/l)	2.1-2.9	9.0-9.3	2.0-2.4	8.7-9.1	2.0-2.4	8.6-9.1
Cr	0.097	0.0	0.057	0.005	0.068	0.005
Cu	0.063	0.018	0.078	0.014	0.053	0.019
Fe	9.24	0.76	15.5	0.92	9.41	0.95
Pb	1.0	0.11	1.36	0.13	1.45	0.11
Mn	0.11	0.06	0.12	0.044	0.11	0.044
Ni	0.077	0.011	0.036	0.009	0.069	0.011
Zn	.054	0.0	0.12	0.0	0.19	0.037
TSS		13		11		11

TABLE VII-3
Effectiveness of Lime and Sodium Hydroxide for Metals Removal

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range (mg/l)	9.2-9.6	8.3-9.8	9.2	7.6-8.1	9.6	7.8-8.2
Al	37.3	0.35	38.1	0.35	29.9	0.35
Co	3.92	0.0	4.65	0.0	4.37	0.0
Cu	0.65	0.003	0.63	0.003	0.72	0.003
Fe	137	0.49	110	0.57	208	0.58
Mn	175	0.12	205	0.012	245	0.12
Ni	6.86	0.0	5.84	0.0	5.63	0.0
Se	28.6	0.0	30.2	0.0	27.4	0.0
Ti	143	0.0	125	0.0	115	0.0
Zn	18.5	0.027	16.2	0.044	17.0	0.01
TSS	4390	9	3595	13	2805	13

TABLE VII-4

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER

	Solubility of metal ion, mg/l		
Metal	As Hydroxide	As Carbonate	As Sulfide
Cadmium (Cd^{++})	2.3×10^{-5}	1.0×10^{-4}	6.7×10^{-10}
Chromium (Cr^{+++})	8.4×10^{-4}		No precipitate
Cobalt (Co^{++})	2.2×10^{-1}		1.0×10^{-8}
Copper (Cu^{++})	2.2×10^{-2}		5.8×10^{-18}
Iron (Fe^{++})	8.9×10^{-1}		3.4×10^{-5}
Lead (Pb^{++})	2.1	7.0×10^{-3}	3.8×10^{-9}
Manganese (Mn^{++})	1.2		2.1×10^{-3}
Mercury (Hg^{++})	3.9×10^{-4}	3.9×10^{-2}	9.0×10^{-20}
Nickel (Ni^{++})	6.9×10^{-3}	1.9×10^{-1}	6.9×10^{-8}
Silver (Ag^{+})	13.3	2.1×10^{-1}	7.4×10^{-12}
Tin (Sn^{++})	1.1×10^{-4}		3.8×10^{-8}
Zinc (Zn^{++})	1.1	7.0×10^{-4}	2.3×10^{-7}

TABLE VII-5

SAMPLING DATA FROM SULFIDE PRECIPITATION-SEDIMENTATION SYSTEMS

Treatment	Lime, FeS, Poly-electrolyte, Settle, Filter		Lime, FeS, Poly-electrolyte, Settle, Filter		NaOH, Ferric Chloride, Na_2S Clarify (1 stage)	
	In	Out	In	Out	In	Out
pH	5.0-6.8	8-9	7.7	7.38		
(mg/l)						
Cr+6	25.6	<0.014	0.022	<0.020	11.45	<.005
Cr	32.3	<0.04	2.4	<0.1	18.35	<.005
Cu	-	-	-	-	0.029	0.003
Fe	0.52	0.10	108	0.6	-	-
Ni	-	-	0.68	<0.1	-	-
Zn	39.5	<0.07	33.9	<0.1	0.060	0.009

These data were obtained from three sources:

> Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.
>
> Industrial Finishing, Vol. 35, No. 11, November, 1979.
>
> Electroplating sampling data from plant 27045.

TABLE VII-6

SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE

Parameter	Treated Effluent (mg/l)
Cd	0.01
CrT	0.05
Cu	0.05
Pb	0.01
Hg	0.03
Ni	0.05
Ag	0.05
Zn	0.01

Table VII-6 is based on two reports:

Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.

Addendum to Development Document for Effluent Limitations Guidelines and New Source Performance Standards, Major Inorganic products Segment of Inorganics Point Source Category, USEPA., EPA Contract No. EPA-68-01-3281 (Task 7), June, 1978.

Table VII-7

FERRITE CO-PRECIPITATION PERFORMANCE

Metal	Influent(mg/l)	Effluent(mg/l)
Mercury	7.4	0.001
Cadmium	240	0.008
Copper	10	0.010
Zinc	18	0.016
Chromium	10	<0.010
Manganese	12	0.007
Nickel	1,000	0.200
Iron	600	0.06
Bismuth	240	0.100
Lead	475	0.010

NOTE: These data are from:
Sources and Treatment of Wastewater in the Nonferrous Metals Industry, USEPA, EPA No. 600/2-80-074, 1980.

TABLE VII-8

CONCENTRATION OF TOTAL CYANIDE
(mg/l)

Plant	Method	In	Out
1057	$FeSO_4$	2.57	0.024
		2.42	0.015
		3.28	0.032
33056	$FeSO_4$	0.14	0.09
		0.16	0.09
12052	$ZnSO_4$	0.46	0.14
		0.12	0.06
Mean			0.07

Table VII-9

Multimedia Filter Performance

Plant ID #	TSS Effluent Concentration, mg/l
06097	0.0, 0.0, 0.5
13924	1.8, 2.2, 5.6, 4.0, 4.0, 3.0, 2.2, 2.8 3.0, 2.0, 5.6, 3.6, 2.4, 3.4
18538	1.0
30172	1.4, 7.0, 1.0
36048	2.1, 2.6, 1.5
mean	2.61

TABLE VII-10
PERFORMANCE OF SELECTED SETTLING SYSTEMS

PLANT ID	SETTLING DEVICE	SUSPENDED SOLIDS CONCENTRATION (mg/l) Day 1		Day 2		Day 3	
		In	Out	In	Out	In	Out
01057	Lagoon	54	6	56	6	50	5
09025	Clarifier Settling Ponds	1100	9	1900	12	1620	5
11058	Clarifier	451	17	-	-	-	-
12075	Settling Pond	284	6	242	10	502	14
19019	Settling Tank	170	1	50	1	-	-
33617	Clarifier & Lagoon	-	-	1662	16	1298	4
40063	Clarifier	4390	9	3595	12	2805	13
44062	Clarifier	182	13	118	14	174	23
46050	Settling Tank	295	10	42	10	153	8

Table VII-11

SKIMMING PERFORMANCE

Plant	Skimmer Type	Oil & Grease mg/l In	Oil & Grease mg/l Out
06058	API	224,669	17.9
06058	Belt	19.4	8.3

TABLE VII-12

SELECTED PARITION COEFFICIENTS

PAH Priority Pollutant		Log Octanol/Water Partition Coefficient
1	Acenaphthene	4.33
39	Fluoranthene	5.33
72	Benzo(a)anthracene	5.61
73	Benzo(a)pyrene	6.04
74	3,4-benzofluoranthene	6.57
75	Benzo(k)fluoranthene	6.84
76	Chrysene	5.61
77	Acenaphthylene	4.07
78	Anthracene	4.45
79	Benzo(ghi)perylene	7.23
80	Fluorene	4.18
81	Phenanthrene	4.46
82	Dibenzo(a,h)anthracene	5.97
83	Indeno(1,2,3,cd)pyrene	7.66
84	Pyrene	5.32

TABLE VII-13

TRACE ORGANIC REMOVAL BY SKIMMING
API PLUS BELT SKIMMERS
(From Plant 06058)

	Inf.	Eff.
Oil & Grease	225,000	14.6
Chloroform	0.023	0.007
Methylene Chloride	0.013	0.012
Naphthalene	2.31	0.004
N-nitrosodiphenylamine	59.0	0.182
Bis-2-ethylhexylphthalate	11.0	0.027
Diethyl phthalate	-	-
Butylbenzylphthalate	0.005	0.002
Di-n-octyl phthalate	0.019	0.002
Anthracene - phenanthrene	16.4	0.014
Toluene	0.02	0.012

Table VII-14

COMBINED METALS DATA EFFLUENT VALUES (mg/l)

	Mean	One Day Max.	10 Day Avg. Max.	30 Day Avg. Max.
Cd	0.079	0.32	0.15	0.13
Cr	0.08	0.42	0.17	0.12
Cu	0.58	1.90	1.00	0.73
Pb	0.12	0.15	0.13	0.12
Ni	0.57	1.41	1.00	0.75
Zn	0.30	1.33	0.56	0.41
Fe	0.41	1.23	0.63	0.51
Mn	0.21	0.43	0.34	0.27
TSS	12.0	41.0	20.0	15.5

TABLE VII-15
L&S PERFORMANCE
ADDITIONAL POLLUTANTS

Pollutant	Average Performance (mg/l)
Sb	0.7
As	0.51
Be	0.30
Hg	0.06
Se	0.30
Ag	0.10
Th	0.50
Al	1.11
Co	0.05
F	14.5

TABLE VII-16

COMBINED METALS DATA SET - UNTREATED WASTEWATER

Pollutant	Min. Conc (mg/l)	Max. Conc. (mg/l)
Cd	<0.1	3.83
Cr	<0.1	116
Cu	<0.1	108
Pb	<0.1	29.2
Ni	<0.1	27.5
Zn	<0.1	337.
Fe	<0.1	263
Mn	<0.1	5.98
TSS	4.6	4390

TABLE VII-17
MAXIMUM POLLUTANT LEVEL IN UNTREATED WASTEWATER

ADDITIONAL POLLUTANTS
(mg/l)

Pollutant	As & Se	Be	Ag	F
As	4.2	-	-	-
Be	-	10.24	-	-
Cd	<0.1	-	<0.1	<0.1
Cr	0.18	8.60	0.23	22.8
Cu	33.2	1.24	110.5	2.2
Pb	6.5	0.35	11.4	5.35
Ni	-	-	100	0.69
Ag	-	-	4.7	-
Zn	3.62	0.12	1512	<0.1
F	-	-	-	760
Fe	-	646	-	-
O&G	16.9	-	16	2.8
TSS	352	796	587.8	5.6

TABLE VII-18

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant A

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	47	0.015 - 0.13	0.045 ±0.029	0.10
Cu	12	0.01 - 0.03	0.019 ±0.006	0.03
Ni	47	0.08 - 0.64	0.22 ±0.13	0.48
Zn	47	0.08 - 0.53	0.17 ±0.09	0.35
Fe				
For 1978-Treated Wastewater				
Cr	47	0.01 - 0.07	0.06 ±0.10	0.26
Cu	28	0.005 - 0.055	0.016 ±0.010	0.04
Ni	47	0.10 - 0.92	0.20 ±0.14	0.48
Zn	47	0.08 - 2.35	0.23 ±0.34	0.91
Fe	21	0.26 - 1.1	0.49 ±0.18	0.85
Raw Waste				
Cr	5	32.0 - 72.0		
Cu	5	0.08 - 0.45		
Ni	5	1.65 - 20.0		
Zn	5	33.2 - 32.0		
Fe	5	10.0 - 95.0		

TABLE VII-19

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant B

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	175	0.0 - 0.40	0.068 ±0.075	0.22
Cu	176	0.0 - 0.22	0.024 ±0.021	0.07
Ni	175	0.01 - 1.49	0.219 ±0.234	0.69
Zn	175	0.01 - 0.66	0.054 ±0.064	0.18
Fe	174	0.01 - 2.40	0.303 ±0.398	1.10
TSS	2	1.00 - 1.00		
For 1978-Treated Wastewater				
Cr	144	0.0 - 0.70	0.059 ±0.088	0.24
Cu	143	0.0 - 0.23	0.017 ±0.020	0.06
Ni	143	0.0 - 1.03	0.147 ±0.142	0.43
Zn	131	0.0 - 0.24	0.037 ±0.034	0.11
Fe	144	0.0 - 1.76	0.200 ±0.223	0.47
Total 1974-1979-Treated Wastewater				
Cr	1288	0.0 - 0.56	0.038 ±0.055	0.15
Cu	1290	0.0 - 0.23	0.011 ±0.016	0.04
Ni	1287	0.0 - 1.88	0.184 ±0.211	0.60
Zn	1273	0.0 - 0.66	0.035 ±0.045	0.13
Fe	1287	0.0 - 3.15	0.402 ±0.509	1.42
Raw Waste				
Cr	3	2.80 - 9.15	5.90	
Cu	3	0.09 - 0.27	0.17	
Ni	3	1.61 - 4.89	3.33	
Zn	2	2.35 - 3.39		
Fe	3	3.13 -35.9	22.4	
TSS	2	177 -466.		

TABLE VII-19

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant B

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	175	0.0 - 0.40	0.068 ±0.075	0.22
Cu	176	0.0 - 0.22	0.024 ±0.021	0.07
Ni	175	0.01 - 1.49	0.219 ±0.234	0.69
Zn	175	0.01 - 0.66	0.054 ±0.064	0.18
Fe	174	0.01 - 2.40	0.303 ±0.398	1.10
TSS	2	1.00 - 1.00		
For 1978-Treated Wastewater				
Cr	144	0.0 - 0.70	0.059 ±0.088	0.24
Cu	143	0.0 - 0.23	0.017 ±0.020	0.06
Ni	143	0.0 - 1.03	0.147 ±0.142	0.43
Zn	131	0.0 - 0.24	0.037 ±0.034	0.11
Fe	144	0.0 - 1.76	0.200 ±0.223	0.47
Total 1974-1979-Treated Wastewater				
Cr	1288	0.0 - 0.56	0.038 ±0.055	0.15
Cu	1290	0.0 - 0.23	0.011 ±0.016	0.04
Ni	1287	0.0 - 1.88	0.184 ±0.211	0.60
Zn	1273	0.0 - 0.66	0.035 ±0.045	0.13
Fe	1287	0.0 - 3.15	0.402 ±0.509	1.42
Raw Waste				
Cr	3	2.80 - 9.15	5.90	
Cu	3	0.09 - 0.27	0.17	
Ni	3	1.61 - 4.89	3.33	
Zn	2	2.35 - 3.39		
Fe	3	3.13 -35.9	22.4	
TSS	2	177 -466.		

TABLE VII-20

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant C

For Treated Wastewater Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For Treated Wastewater				
Cd	103	0.010 - 0.500	0.049 ±0.049	0.147
Zn	103	0.039 - 0.899	0.290 ±0.131	0.552
TSS	103	0.100 - 5.00	1.244 ±1.043	3.33
pH	103	7.1 - 7.9	9.2*	
For Untreated Wastewater				
Cd	103	0.039 - 2.319	0.542 ±0.381	1.304
Zn	103	0.949 -29.8	11.009 ±6.933	24.956
Fe	3	0.107 - 0.46	0.255	
TSS	103	0.80 -19.6	5.616 ±2.896	11.408
pH	103	6.8 - 8.2	7.6*	

* pH value is median of 103 values.

TABLE VII-21

Summary of Treatment Effectiveness
(mg/l)

Pollutant Parameter		L&S Technology System				LS&F Technology System			
		Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.	Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.
114	Sb	0.70	2.87	1.28	1.14	0.47	1.93	0.86	0.76
115	As	0.51	2.09	0.86	0.83	0.34	1.39	0.57	0.55
117	Be	0.30	1.23	0.51	0.49	0.20	0.82	0.34	0.32
118	Cd	0.079	0.32	0.15	0.13	0.049	0.20	0.08	0.08
119	Cr	0.080	0.42	0.17	0.12	0.07	0.37	0.15	0.10
120	Cu	0.58	1.90	1.00	0.73	0.39	1.28	0.61	0.49
121	CN	0.07	0.29	0.12	0.11	0.047	0.20	0.08	0.08
122	Pb	0.12	0.15	0.13	0.12	0.08	0.10	0.09	0.08
123	Hg	0.06	0.25	0.10	0.10	0.036	0.15	0.06	0.06
124	Ni	0.57	1.41	1.00	0.75	0.22	0.55	0.37	0.29
125	Se	0.30	1.23	0.55	0.49	0.20	0.82	0.37	0.33
126	Ag	0.10	0.41	0.17	0.16	0.07	0.29	0.12	0.10
127	Tl	0.50	2.05	0.84	0.81	0.34	1.40	0.57	0.55
128	Zn	0.30	1.33	0.56	0.41	0.23	1.02	0.42	0.31
	Al	1.11	4.55	1.86	1.80	0.74	3.03	1.24	1.20
	Co	0.05	0.21	0.09	0.08	0.034	0.14	0.07	0.06
	F	14.5	59.5	26.4	23.5	9.67	39.7	17.6	15.7
	Fe	0.41	1.23	0.63	0.51	0.28	1.23	0.63	0.51
	Mn	0.21	0.43	0.34	0.27	0.14	0.30	0.23	0.19
	P	4.08	16.7	6.83	6.60	2.72	11.2	4.6	4.4
	O&G		20.0	12.0	10.0		10.0	10.0	10.0
	TSS	12.0	41.0	20.0	15.5	2.6	15.0	12.0	10.0

TABLE VII-22
TREATABILITY RATING OF PRIORITY POLLUTANTS UTILIZING CARBON ADSORPTION

Priority Pollutant	*Removal Rating
1. acenaphthene	H
2. acrolein	L
3. acrylonitrile	L
4. benzene	M
5. benzidine	H
6. carbon tetrachloride (tetrachloromethane)	M
7. chlorobenzene	H
8. 1,2,3-trichlorobenzene	H
9. hexachlorobenzene	H
10. 1,2-dichloroethane	M
11. 1,1,1-trichloroethane	M
12. hexachloroethane	H
13. 1,1-dichloroethane	M
14. 1,1,2-trichloroethane	M
15. 1,1,2,2-tetrachlorethane	H
16. chloroethane	L
17. bis(chloromethyl) ether	-
18. bis(2-chloroethyl) ether	M
19. 2-chloroethylvinyl ether (mixed)	L
20. 2-chloronaphthalene	H
21. 2,4,6-trichlorophenol	H
22. parachlorometa cresol	H
23. chloroform (trichloromethane)	L
24. 2-chlorophenol	H
25. 1,2-dichlorobenzene	H
26. 1,3-dichlorobenzene	H
27. 1,4-dichlorobenzene	H
28. 3,3'-dichlorobenzidine	H
29. 1,1-dichloroethylene	L
30. 1,2-trans-dichloroethylene	L
31. 2,4-dichlorophenol	H
32. 1,2-dichloropropane	M
33. 1,2-dichloropropylene (1,3-dichloropropene)	M
34. 2,4-dimethylphenol	H
35. 2,4-dinitrotoluene	H
36. 2,6-dinitrotoluene	H
37. 1,2-diphenylhydrazine	H
38. ethylbenzene	M
39. fluoranthene	H
40. 4-chlorophenyl phenyl ether	H
41. 4-bromophenyl phenyl ether	H
42. bis(2-chloroisopropyl)ether	M
43. bis(2-chloroethoxy)methane	M
44. methylene chloride (dichloromethane)	L
45. methyl chloride (chloromethane)	L
46. methyl bromide (bromomethane)	L
47. bromoform (tribromomethane)	H
48. dichlorobromomethane	M
49. trichlorofluoromethane	M
50. dichlorodifluoromethane	L
51. chlorodibromomethane	M
52. hexachlorobutadiene	H
53. hexachlorocyclopentadiene	H
54. isophorone	H
55. naphthalene	H
56. nitrobenzene	H
57. 2-nitrophenol	H
58. 4-nitrophenol	H
59. 2,4-dinitrophenol	H
60. 4,6-dinitro-o-cresol	H
61. N-nitrosodimethylamine	M
62. N-nitrosodiphenylamine	H
63. N-nitrosodi-n-propylamine	M
64. pentachlorophenol	H
65. phenol	M
66. bis(2-ethylhexyl)phthalate	H
67. butyl benzyl phthalate	H
68. di-n-butyl phthalate	H
69. di-n-octyl phthalate	H
70. diethyl phthalate	H
71. dimethyl phthalate	H
72. 1,2-benzanthracene (benzo(a)anthracene)	H
73. benzo(a)pyrene (3,4-benzopyrene)	H
74. 3,4-benzofluoranthene (benzo(b)fluoranthene)	H
75. 11,12-benzofluoranthene (benzo(k)fluoranthene)	H
76. chrysene	H
77. acenaphthylene	H
78. anthracene	H
79. 1,12-benzoperylene (benzo (ghi)-perylene)	H
80. fluorene	H
81. phenanthrene	H
82. 1,2,3,6-dibenzanthracene (dibenzo(a,h) anthracene)	H
83. indeno (1,2,3-cd) pyrene (2,3-o-phenylene pyrene)	H
84. pyrene	-
85. tetrachloroethylene	M
86. toluene	M
87. trichloroethylene	L
88. vinyl chloride (chloroethylene)	L
106. PCB-1242 (Aroclor 1242)	H
107. PCB-1254 (Aroclor 1254)	H
108. PCB-1221 (Aroclor 1221)	H
109. PCB-1332 (Aroclor 1232)	H
110. PCB-1248 (Aroclor 1248)	H
111. PCB-1260 (Aroclor 1260)	H
112. PCB-1016 (Aroclor 1016)	H

*Note Explanation of Removal Ratings

Category H (high removal)

adsorbs at levels $\geq$ 100 mg/g carbon at C_f = 10 mg/l

adsorbs at levels $\geq$ 100 mg/g carbon at C_f < 1.0 mg/l

Category M (moderate removal)

adsorbs at levels $\geq$ 100 mg/g carbon at C_f = 10 mg/l

adsorbs at levels $\leq$ 100 mg/g carbon at C_f < 1.0 mg/l

Category L (low removal)

adsorbs at levels < 100 mg/g carbon at C_f = 10 mg/l

adsorbs at levels < 10 mg/g carbon at C_f < 1.0 mg/l

C_f = final concentrations of priority pollutant at equilibrium

TABLE VII - 23

CLASSES OF ORGANIC COMPOUNDS ADSORBED ON CARBON

Organic Chemical Class	Examples of Chemical Class
Aromatic Hydrocarbons	benzene, toluene, xylene
Polynuclear Aromatics	naphthalene, anthracene biphenyls
Chlorinated Aromatics	chlorobenzene, polychlorinated biphenyls, aldrin, endrin, toxaphene, DDT
Phenolics	phenol, cresol, resorcenol and polyphenyls
Chorinated Phenolics	trichlorophenol, pentachlorophenol
*High Molecular Weight Aliphatic and Branch Chain hydrocarbons	gasoline, kerosine
Chlorinated Aliphatic hydrocarbons	carbon tetrachloride, perchloroethylene
*High Molecular Weight Aliphatic Acids and Aromatic Acids	tar acids, benzoic acid
*High Molecular Weight Aliphatic Amines and Aromatic Amines	aniline, toluene diamine
*High Molecular Weight Ketones, Esters, Ethers and Alcohols	hydroquinone, polyethylene glycol
Surfactants	alkyl benzene sulfonates
Soluble Organic Dyes	methylene blue, indigo carmine

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* High Molecular Weight includes compounds in the broad range of from 4 to 20 carbon atoms

Table VII-24

ACTIVATED CARBON PERFORMANCE (MERCURY)

Plant	Mercury levels - mg/l In	 Out
A	28.0	0.9
B	0.36	0.015
C	0.008	0.0005

Table VII-25

Ion Exchange Performance

Parameter	Plant A		Plant B	
All Values mg/l	Prior To Purification	After Purification	Prior To Purification	After Purification
Al	5.6	0.20	-	-
Cd	5.7	0.00	-	-
Cr+3	3.1	0.01	-	-
Cr+6	7.1	0.01	-	-
Cu	4.5	0.09	43.0	0.10
CN	9.8	0.04	3.40	0.09
Au	-	-	2.30	0.10
Fe	7.4	0.01	-	-
Pb	-	-	1.70	0.01
Mn	4.4	0.00	-	-
Ni	6.2	0.00	1.60	0.01
Ag	1.5	0.00	9.10	0.01
SO4	-	-	210.00	2.00
Sn	1.7	0.00	1.10	0.10
Zn	14.8	0.40	-	-

Table VII-26

MEMBRANE FILTRATION SYSTEM EFFLUENT

Specific Metal	Manufacturers Guarantee	Plant 19066 In	Plant 19066 Out	Plant 31022 In	Plant 31022 Out	Predicted Performance
Al	0.5	---	---	---	---	
Cr, (+6)	0.02	0.46	0.01	5.25	<0.005	
Cr (T)	0.03	4.13	0.018	98.4	0.057	0.05
Cu	0.1	18.8	0.043	8.00	0.222	0.20
Fe	0.1	288	0.3	21.1	0.263	0.30
Pb	0.05	0.652	0.01	0.288	0.01	0.05
CN	0.02	<0.005	<0.005	<0.005	<0.005	0.02
Ni	0.1	9.56	0.017	194	0.352	0.40
Zn	0.1	2.09	0.046	5.00	0.051	0.10
TSS	---	632	0.1	13.0	8.0	1.0

Table VII-27

PEAT ADSORPTION PERFORMANCE

Pollutant (mg/l)	In	Out
Cr+6	35,000	0.04
Cu	250	0.24
CN	36.0	0.7
Pb	20.0	0.025
Hg	1.0	0.02
Ni	2.5	0.07
Ag	1.0	0.05
Sb	2.5	0.9
Zn	1.5	0.25

Table VII-28

ULTRAFILTRATION PERFORMANCE

Parameter	Feed (mg/l)	Permeate (mg/l)
Oil (freon extractable)	1230	4
COD	8920	148
TSS	1380	13
Total Solids	2900	296

TABLE VII-29

REMOVAL OF TOXIC ORGANICS BY OIL REMOVAL

Pollutant Parameter		Influent Concentration (mg/l)	Effluent Concentration (mg/l)
001	acenaphthene	5.7	ND
038	ethylbenzene	0.089	0.01
055	naphthalene	0.75	0.23
062	N-nitrosodiphenylamine	1.5	0.091
065	phenol	0.18	0.04
066	bis(2-ethylhexyl)phthalate	1.25	0.01
068	di-n-butyl phthalate	1.27	0.019
078/081	anthracene/phenanthrene	2.0	0.1
080	fluorene	0.76	0.035
084	pyrene	0.075	0.01
085	tetrachloroethylene	4.2	0.1
086	toluene	0.16	0.02
087	trichloroethylene	4.8	0.01
097	endosulfan sulfate	0.012	ND
098	endrin	0.066	0.005
107	PCB-1254 (a)	1.1	0.005
110	PCB-1248 (b)	1.8	0.005
	(mg/l)	25.7	0.690

a: PCB-1242, PCB-1254, PCB-1221, PCB-1232 reported together.
b: PCB-1248, PCB-1260, PCB-1016 reported together.

TABLE VII-30

CHEMICAL EMULSION BREAKING EFFICIENCIES

Parameter	Concentration (mg/l) Influent	 Effluent	Reference
O&G	6,060	98	Sampling data*
TSS	2,612	46	
O&G	13,000	277	Sampling data+
	18,400	--	
	21,300	189	
TSS	540	121	
	680	59	
	1,060	140	
O&G	2,300	52	Sampling data**
	12,500	27	
	13,800	18	
TSS	1,650	187	
	2,200	153	
	3,470	63	
O&G	7,200	80	Katnick and Pavilcius, 1978++

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*Oil and grease and total suspended solids were taken as grab samples before and after batch emulsion breaking treatment which used alum and polymer on emulsified rolling oil wastewater.

+Oil and grease (grab) and total suspended solids (grab) samples were taken on three consecutive days from emulsified rolling oil wastewater. A commercial demulsifier was used in this batch treatment.

**Oil and grease (grab) and total suspended solids (composite) samples were taken on three consecutive days from emulsified rolling oil wastewater. A commercial demulsifier (polymer) was used in this batch treatment.

++This result is from a full-scale batch chemical treatment system for emulsified oils from a steel rolling mill.

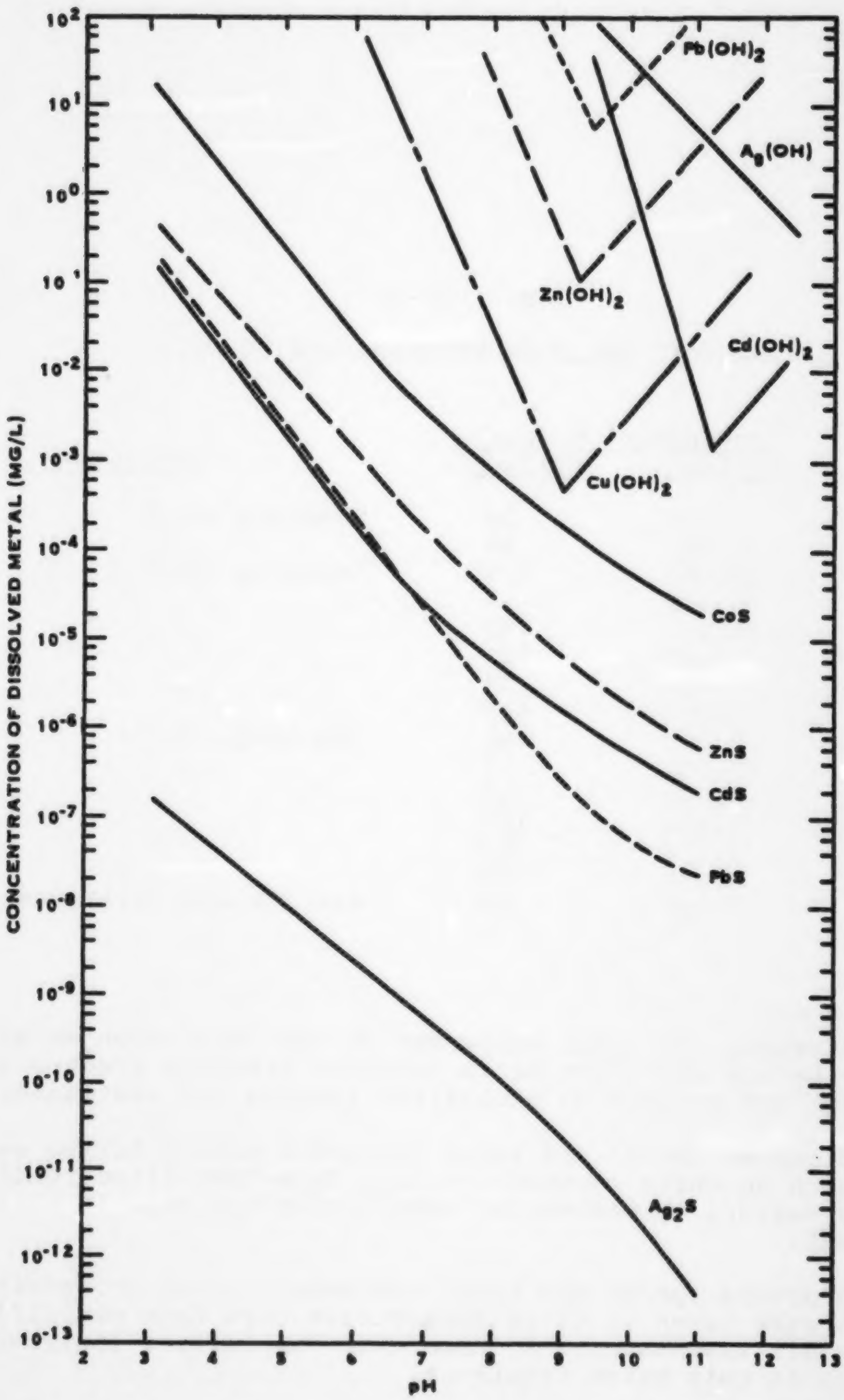


FIGURE VII-1. COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH

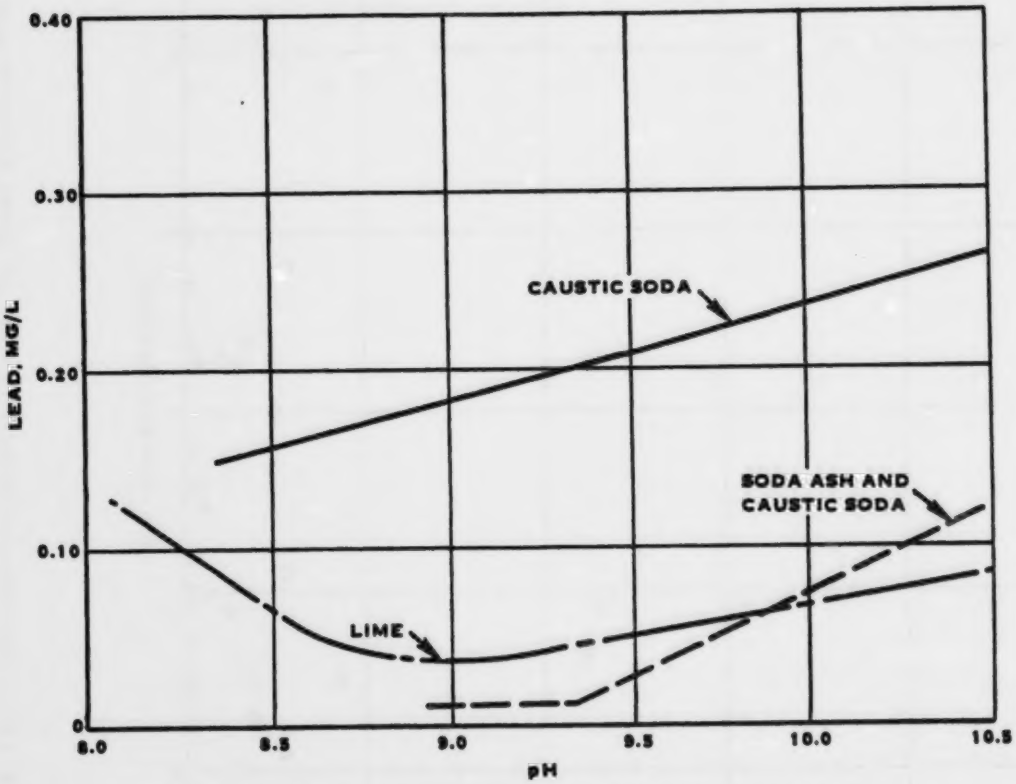


FIGURE VII-2. LEAD SOLUBILITY IN THREE ALKALIES

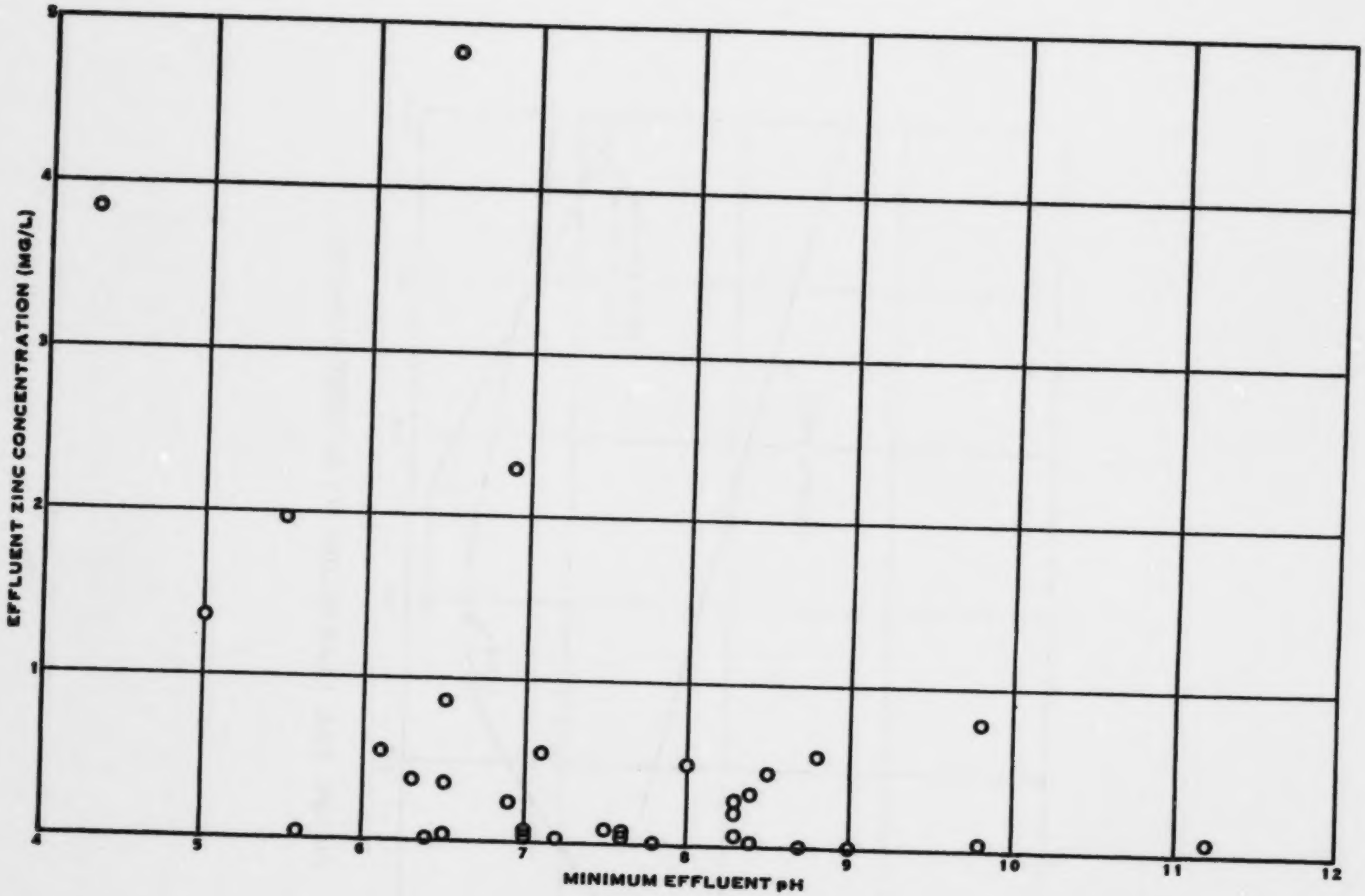
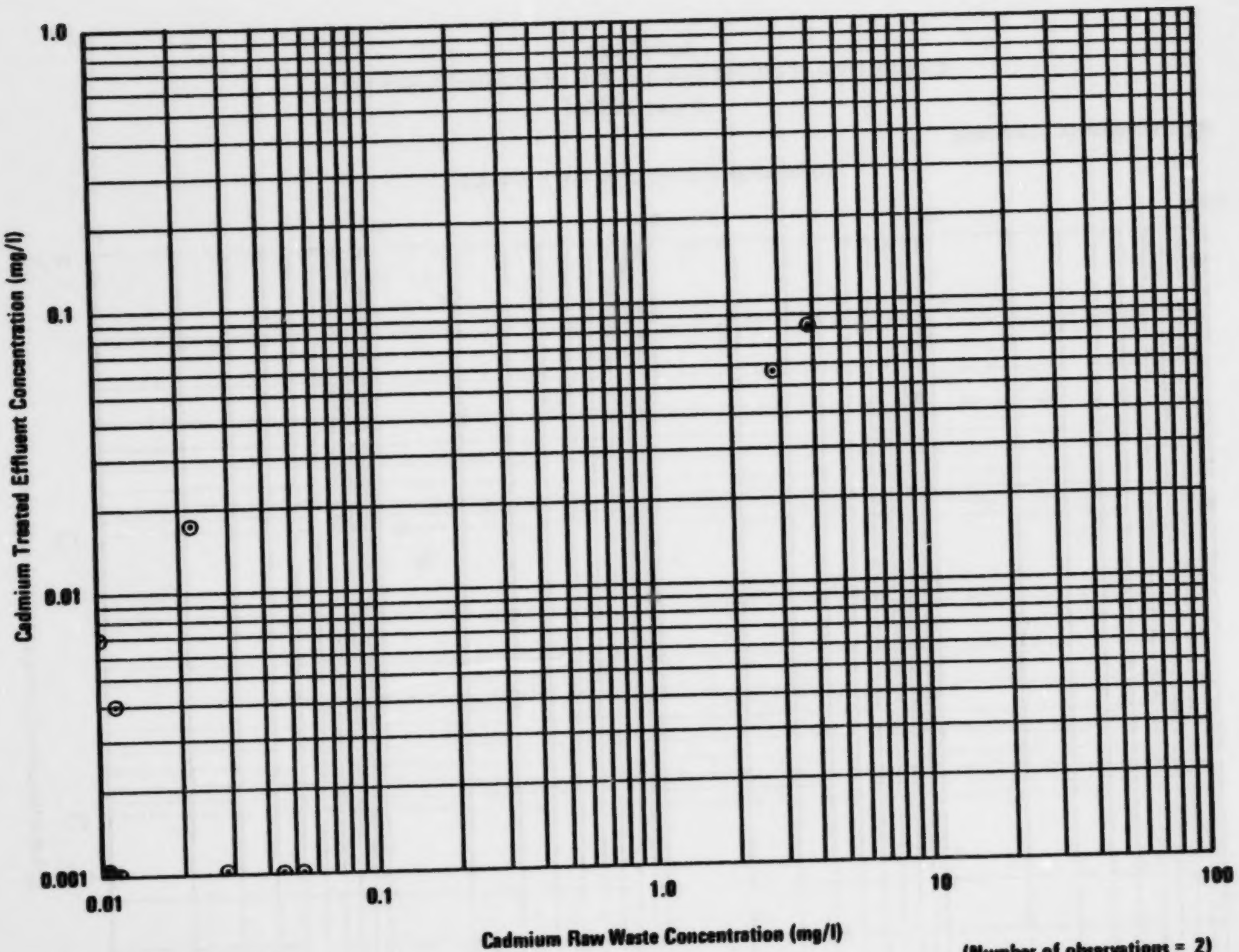


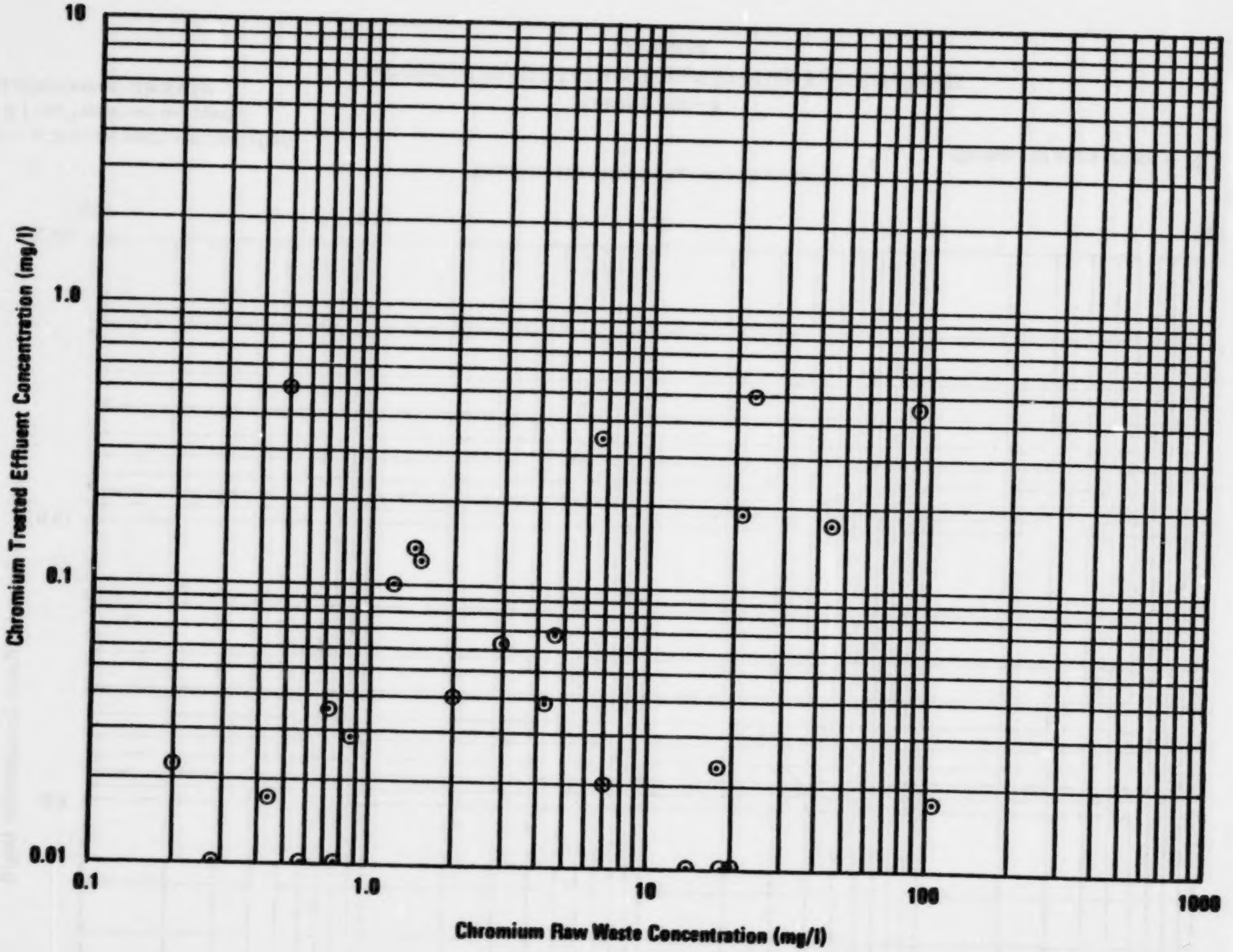
FIGURE VII-3. EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH



(Number of observations = 2)

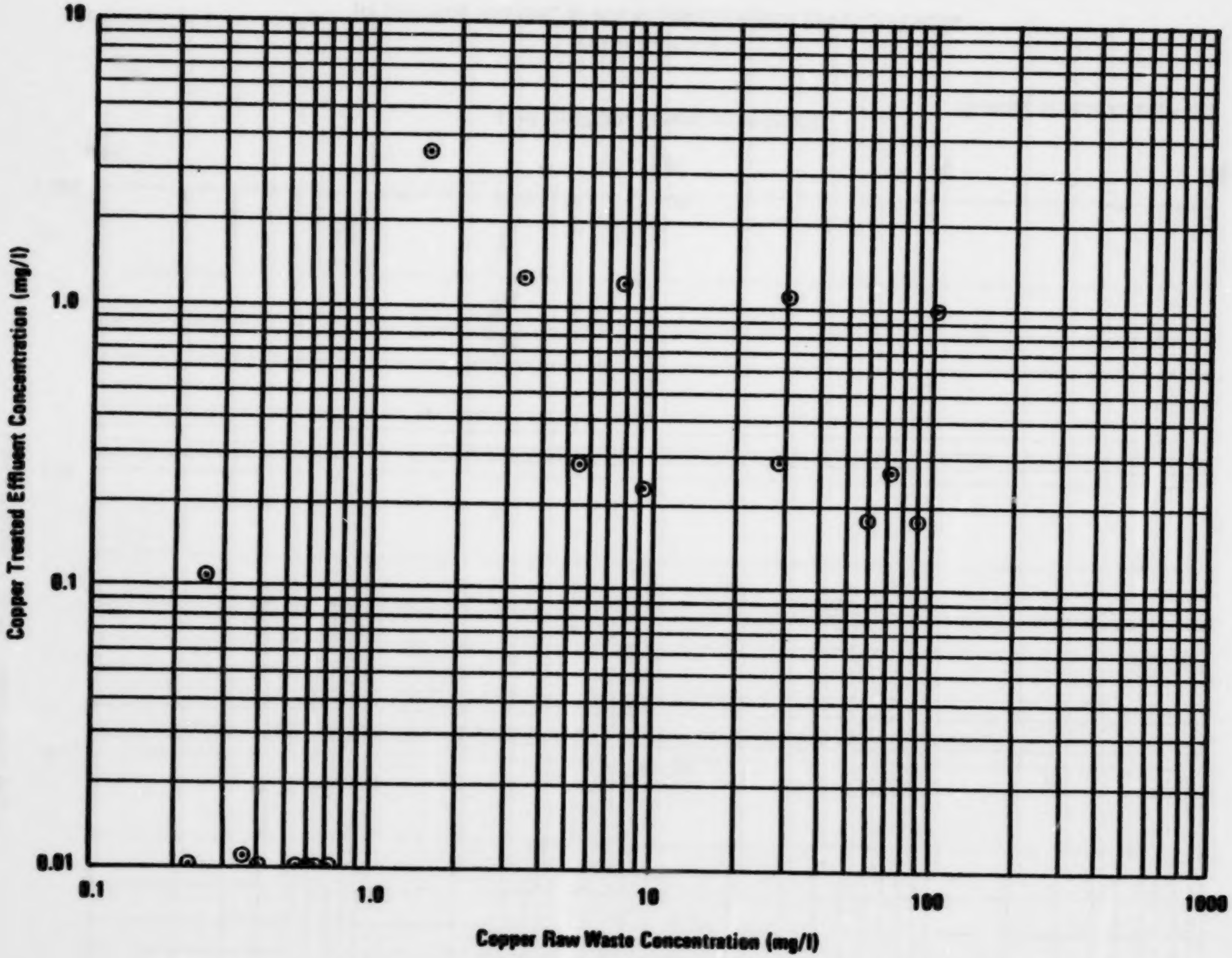
Data points with a raw waste concentration less than 0.1 mg/l were not included in treatment effectiveness calculations.

FIGURE VII-4
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CADMIUM



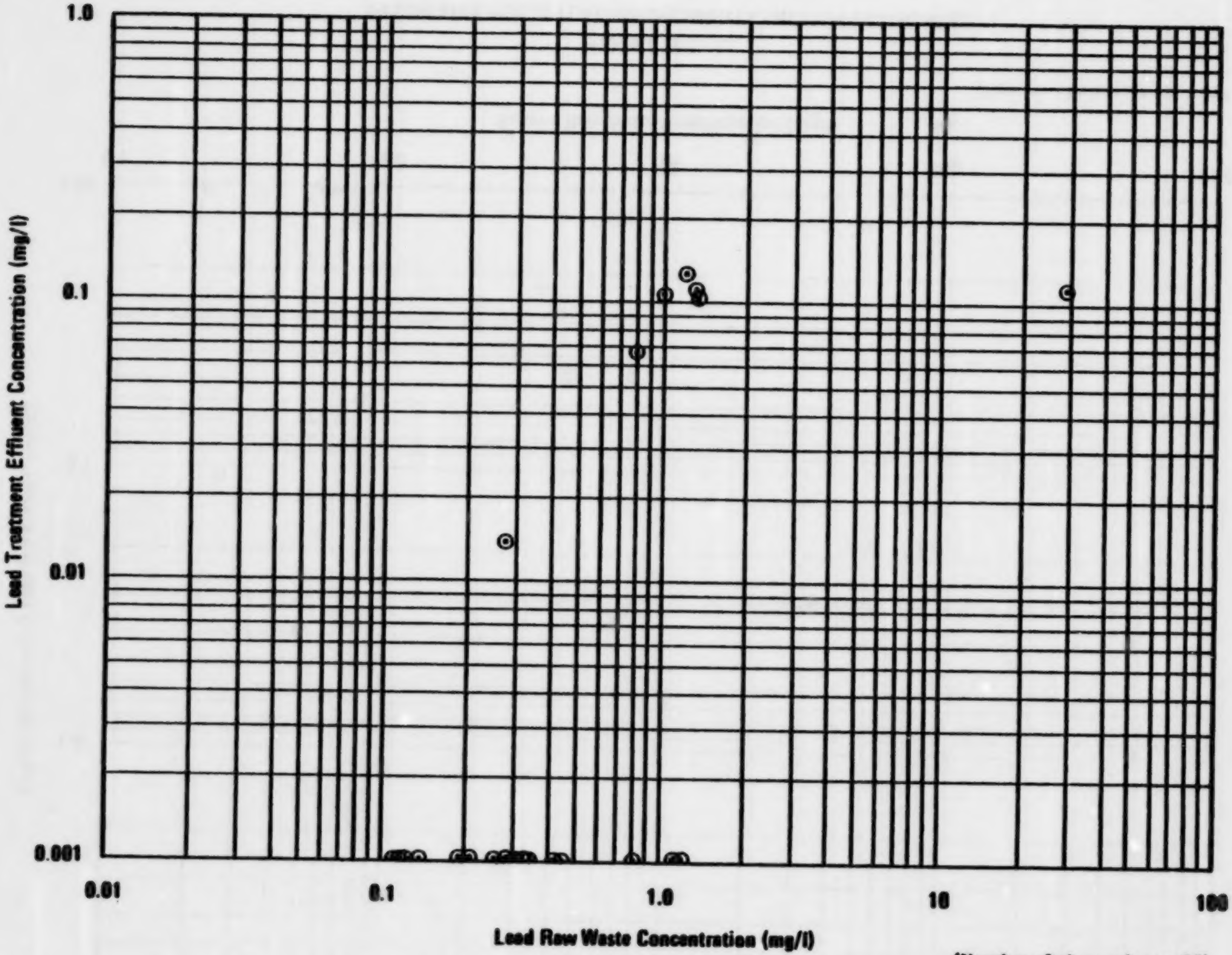
(Number of observations = 26)

FIGURE VII–5
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CHROMIUM



(Number of observations = 19)

FIGURE VII-6
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
COPPER



(Number of observations = 23)

FIGURE VII– 7
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
LEAD

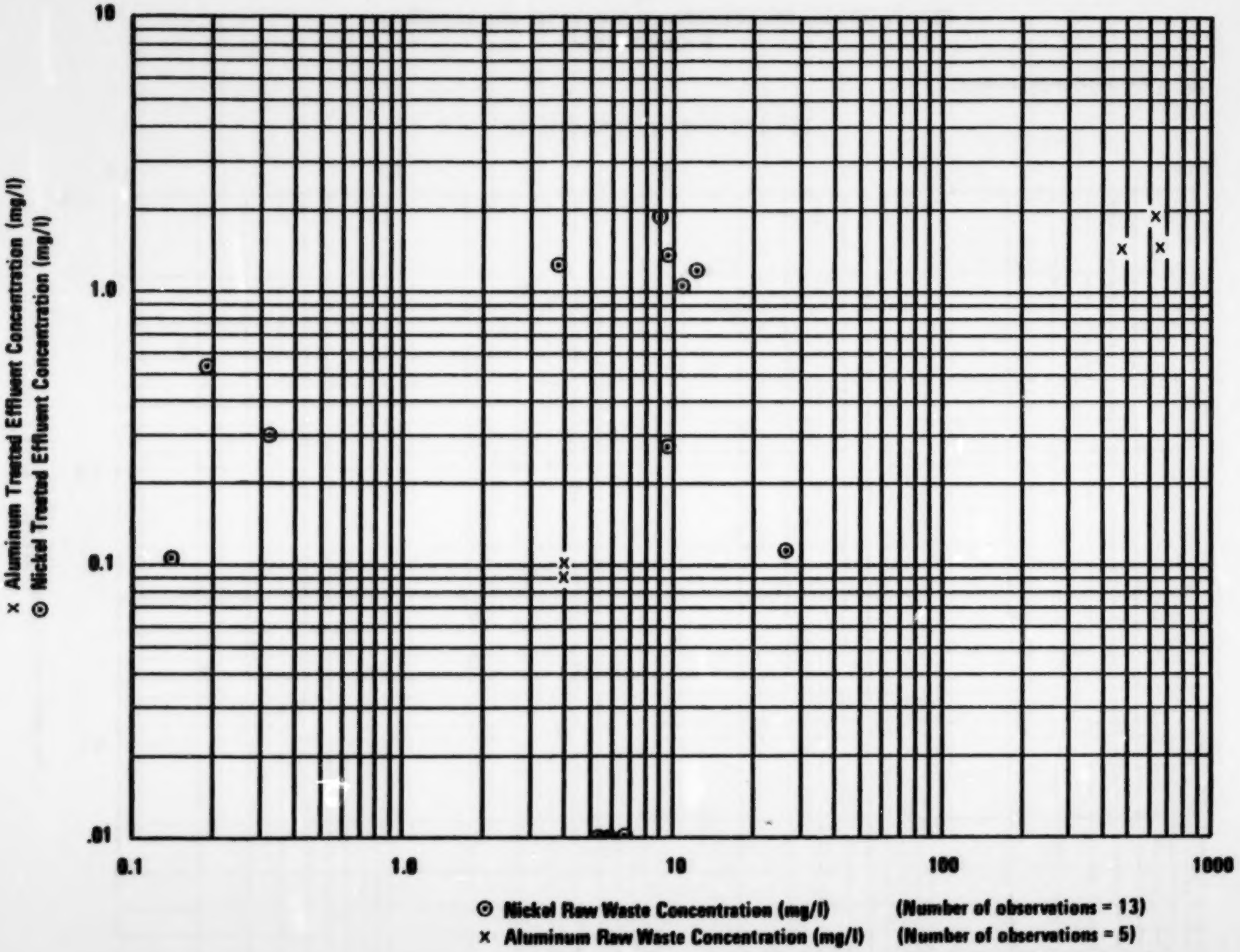
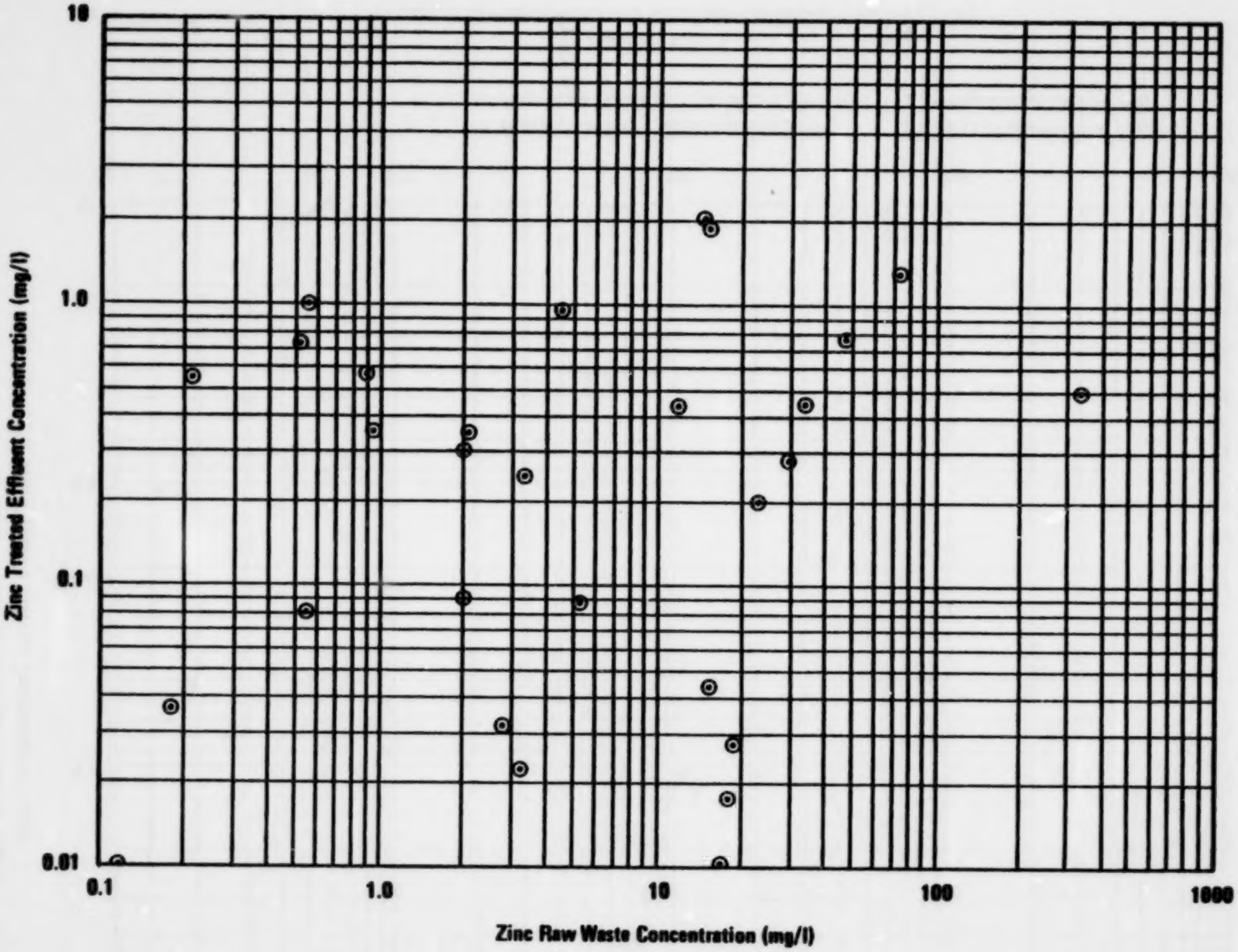
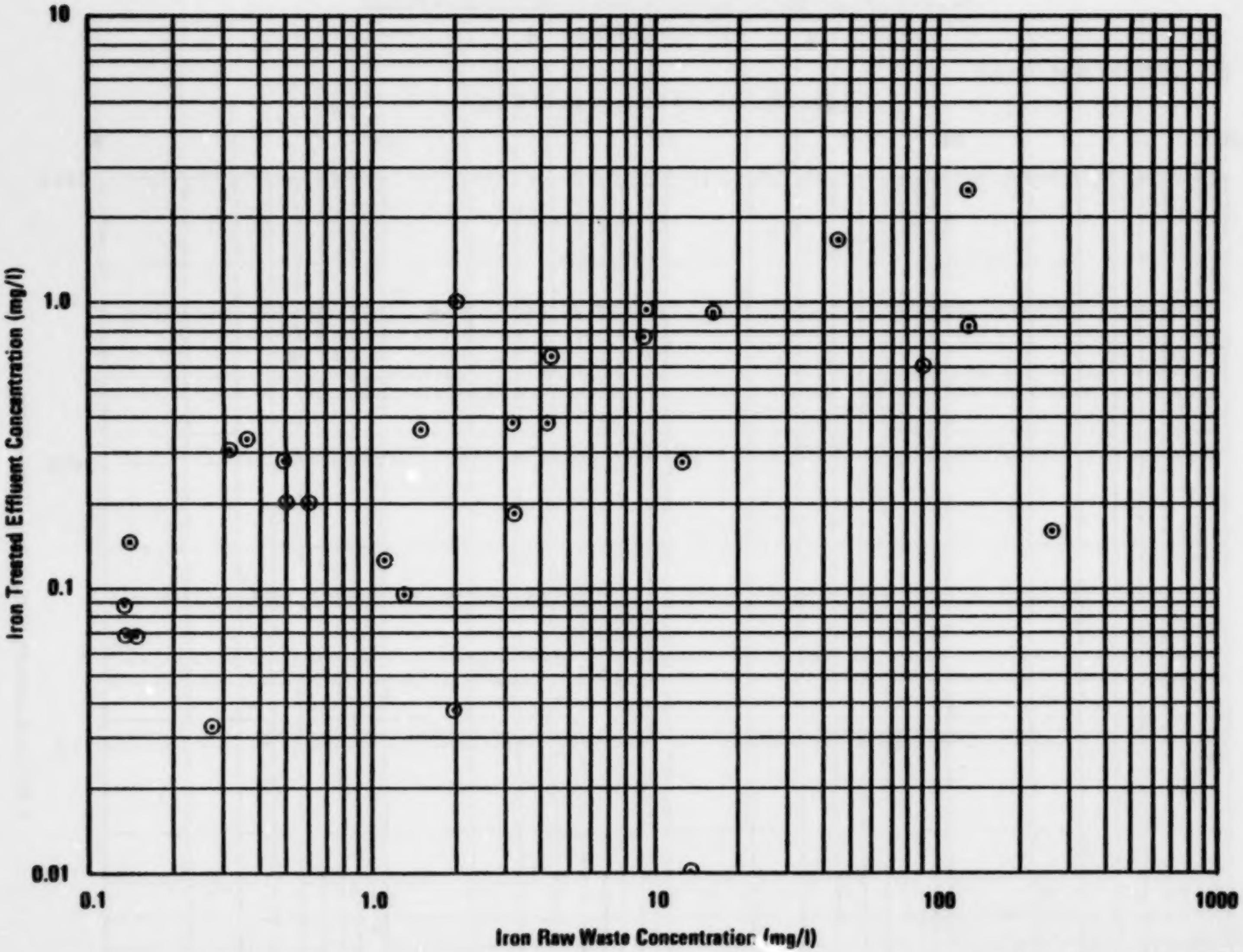


FIGURE VII-8
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
NICKEL AND ALUMINUM



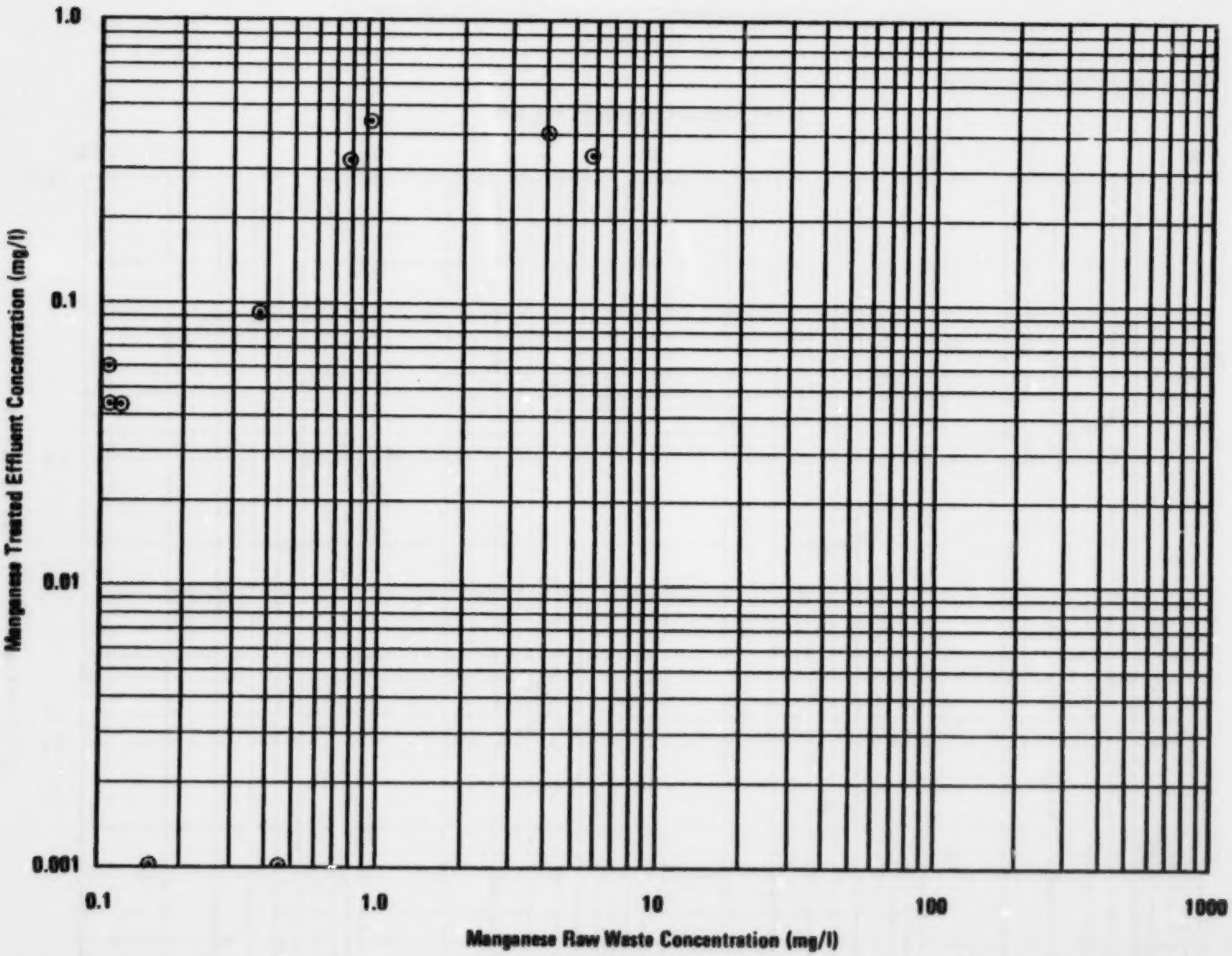
(Number of observations = 29)

FIGURE VII-9
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
ZINC



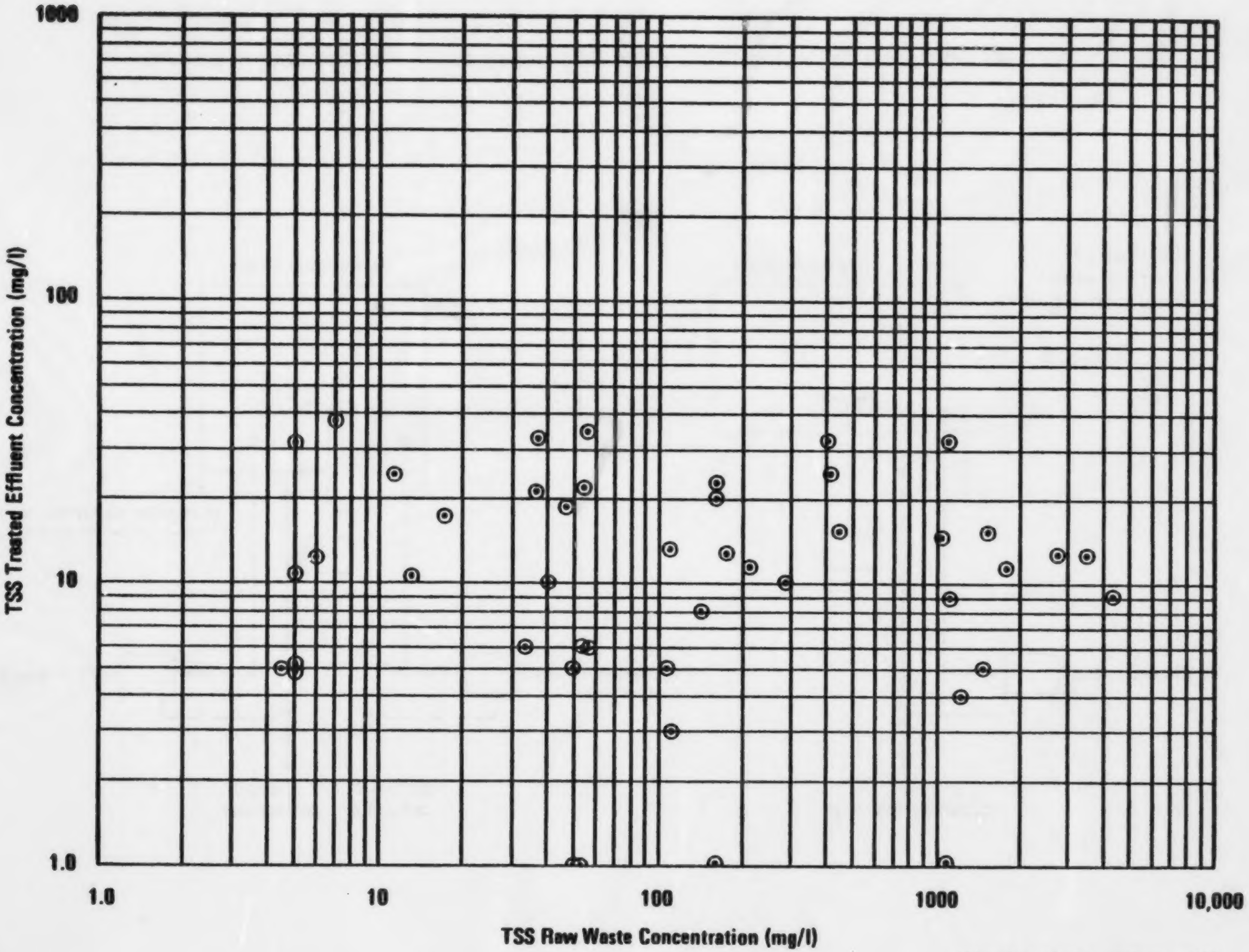
(Number of observations = 29)

FIGURE VII – 10
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
IRON



(Number of observations = 10)

FIGURE VII – 11
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
MANGANESE



(Number of observations = 46)

FIGURE VII–12
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
TSS

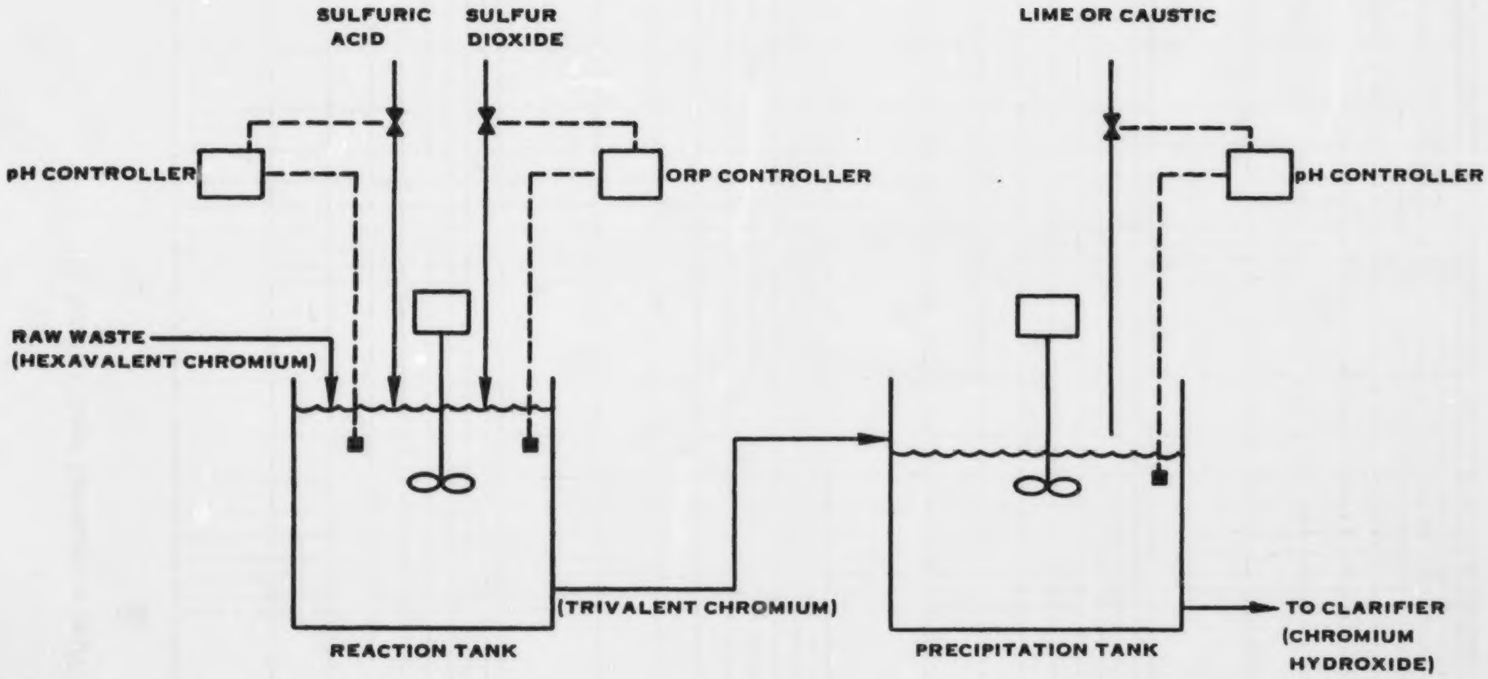

SULFURIC ACID
SULFUR DIOXIDE
LIME OR CAUSTIC
pH CONTROLLER
ORP CONTROLLER
pH CONTROLLER
RAW WASTE (HEXAVALENT CHROMIUM)
(TRIVALENT CHROMIUM)
TO CLARIFIER (CHROMIUM HYDROXIDE)
REACTION TANK
PRECIPITATION TANK

FIGURE VII-13. HEXAVALENT CHROMIUM REDUCTION WITH SULFUR DIOXIDE

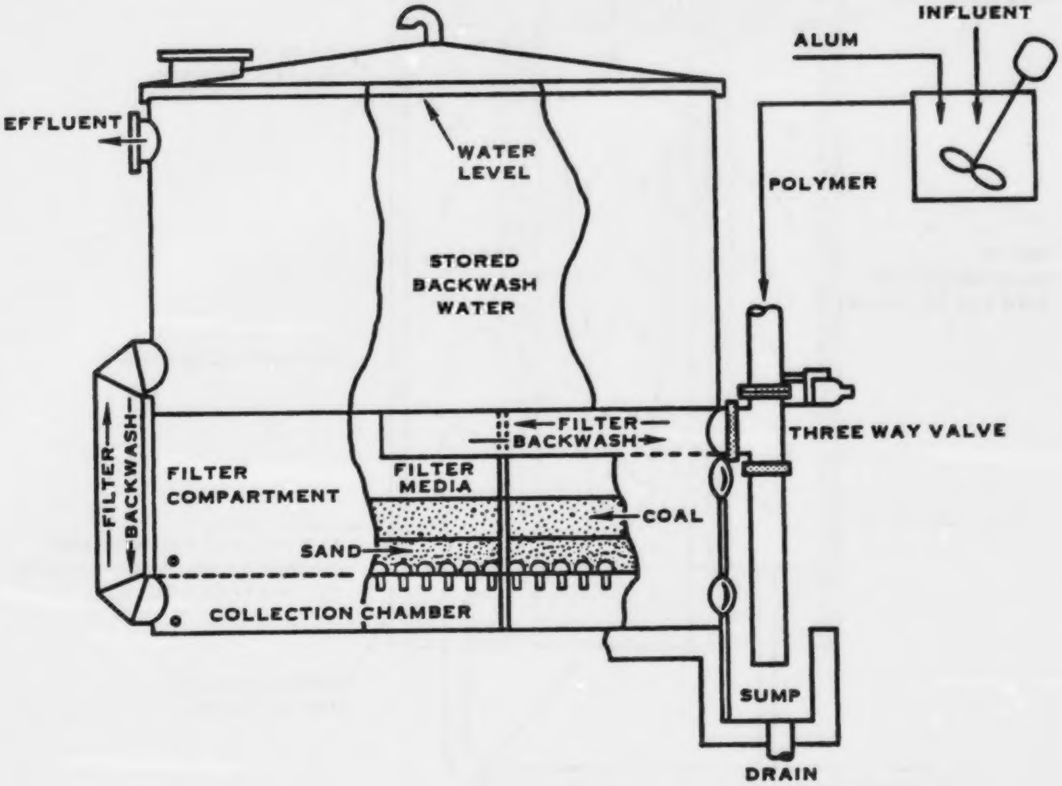

INFLUENT
ALUM
EFFLUENT
WATER LEVEL
POLYMER
STORED BACKWASH WATER
FILTER
BACKWASH
THREE WAY VALVE
FILTER
BACKWASH
FILTER COMPARTMENT
FILTER MEDIA
COAL
SAND
COLLECTION CHAMBER
SUMP
DRAIN

FIGURE VII-14. GRANULAR BED FILTRATION

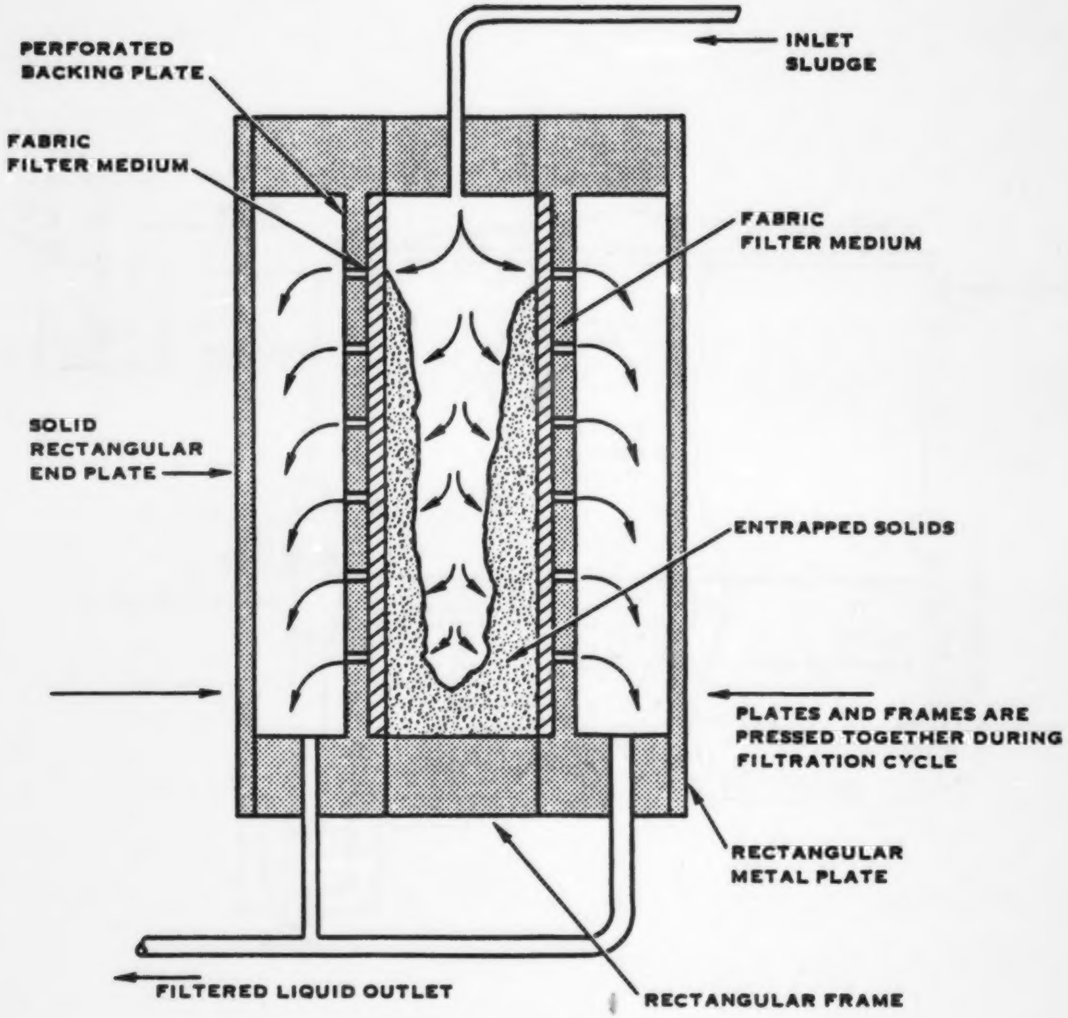
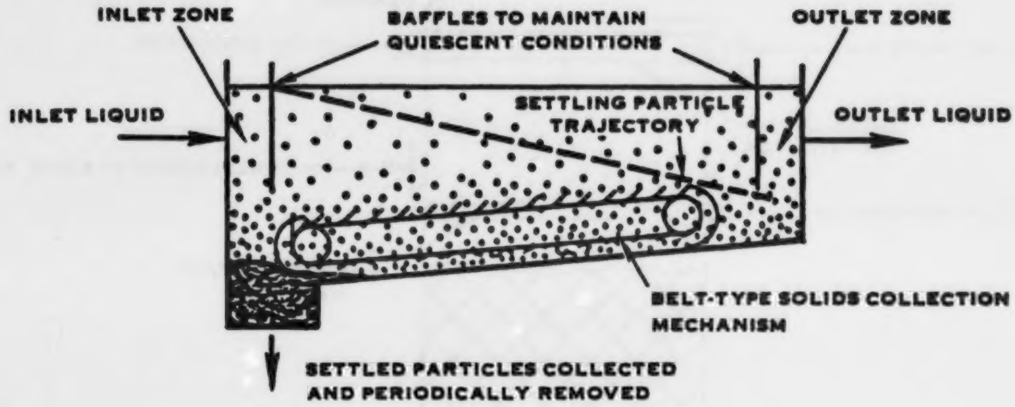

PERFORATED BACKING PLATE
INLET SLUDGE
FABRIC FILTER MEDIUM
FABRIC FILTER MEDIUM
SOLID RECTANGULAR END PLATE
ENTRAPPED SOLIDS
PLATES AND FRAMES ARE PRESSED TOGETHER DURING FILTRATION CYCLE
RECTANGULAR METAL PLATE
FILTERED LIQUID OUTLET
RECTANGULAR FRAME

FIGURE VII-15. PRESSURE FILTRATION

SEDIMENTATION BASIN


INLET ZONE
BAFFLES TO MAINTAIN QUIESCENT CONDITIONS
OUTLET ZONE
INLET LIQUID
SETTLING PARTICLE TRAJECTORY
OUTLET LIQUID
BELT-TYPE SOLIDS COLLECTION MECHANISM
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED

CIRCULAR CLARIFIER

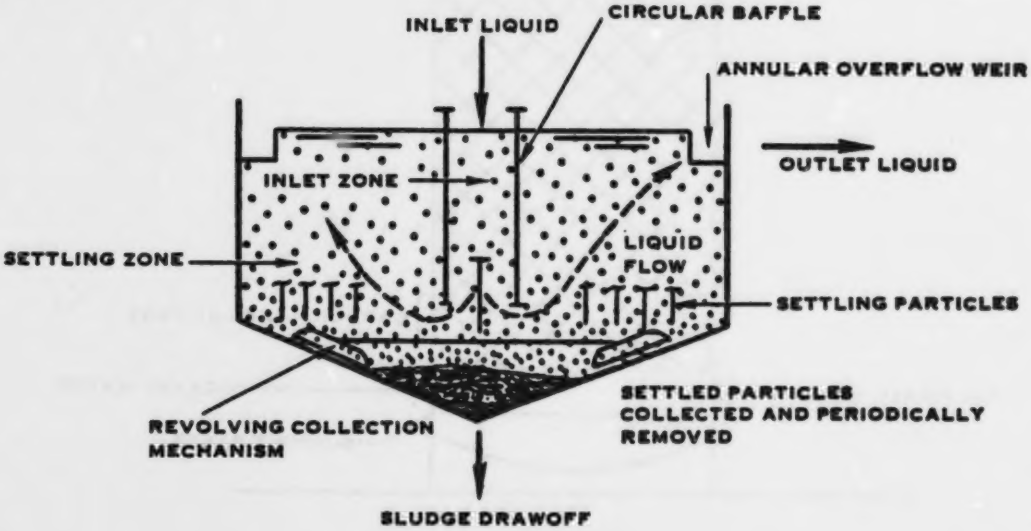

INLET LIQUID
CIRCULAR BAFFLE
ANNULAR OVERFLOW WEIR
OUTLET LIQUID
INLET ZONE
LIQUID FLOW
SETTLING ZONE
SETTLING PARTICLES
REVOLVING COLLECTION MECHANISM
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED
SLUDGE DRAWOFF

FIGURE VII-16. REPRESENTATIVE TYPES OF SEDIMENTATION

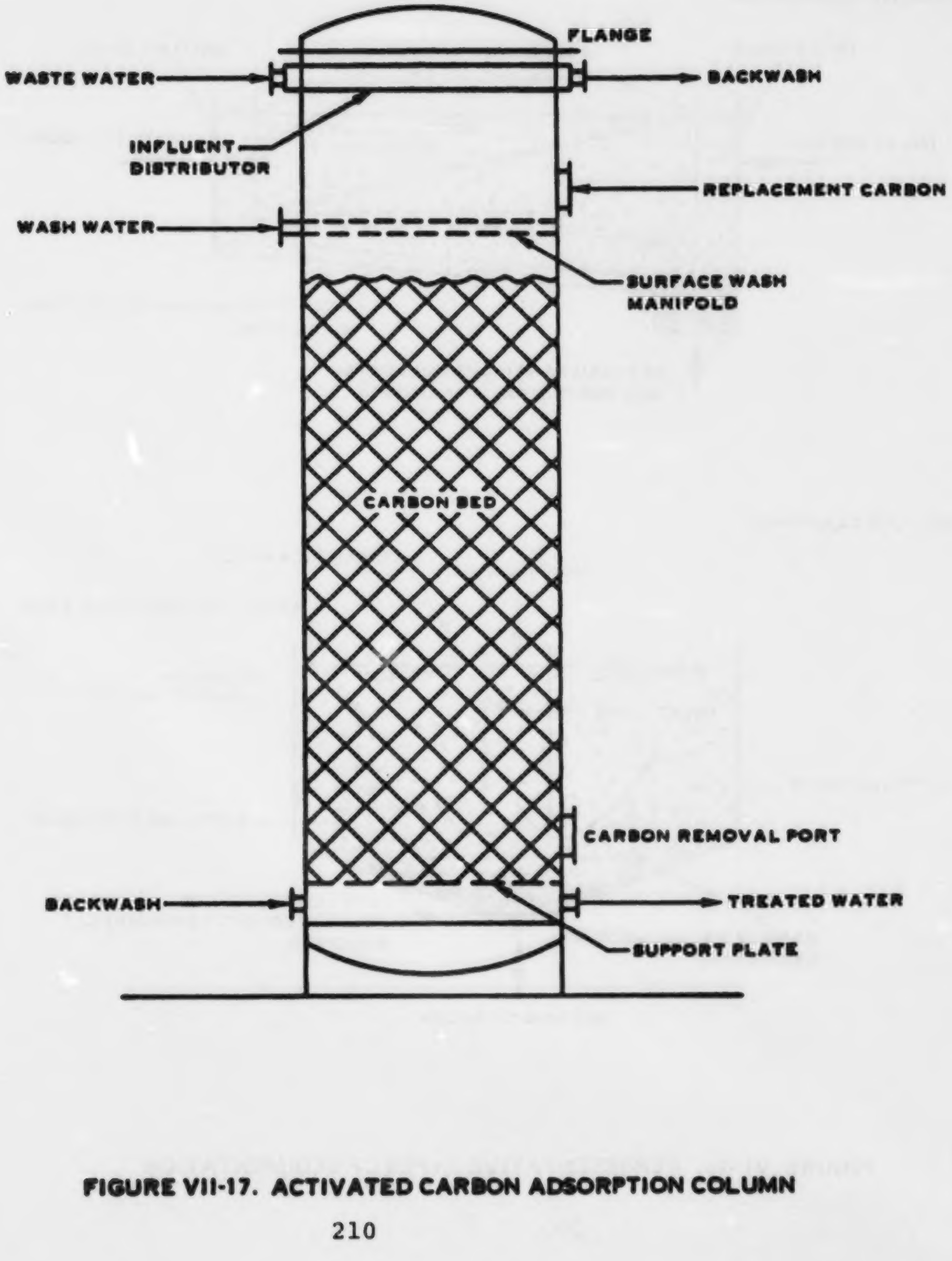

FLANGE
WASTE WATER
BACKWASH
INFLUENT DISTRIBUTOR
REPLACEMENT CARBON
WASH WATER
SURFACE WASH MANIFOLD
CARBON BED
CARBON REMOVAL PORT
BACKWASH
TREATED WATER
SUPPORT PLATE

FIGURE VII-17. ACTIVATED CARBON ADSORPTION COLUMN

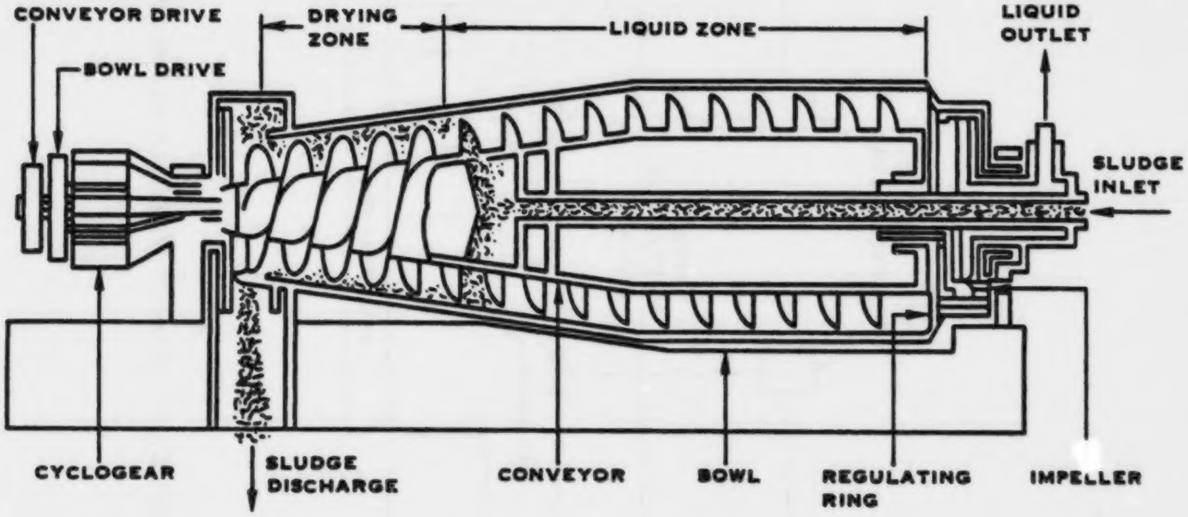

CONVEYOR DRIVE
BOWL DRIVE
DRYING ZONE
LIQUID ZONE
LIQUID OUTLET
SLUDGE INLET
CYCLOGEAR
SLUDGE DISCHARGE
CONVEYOR
BOWL
REGULATING RING
IMPELLER

FIGURE VII-18. CENTRIFUGATION

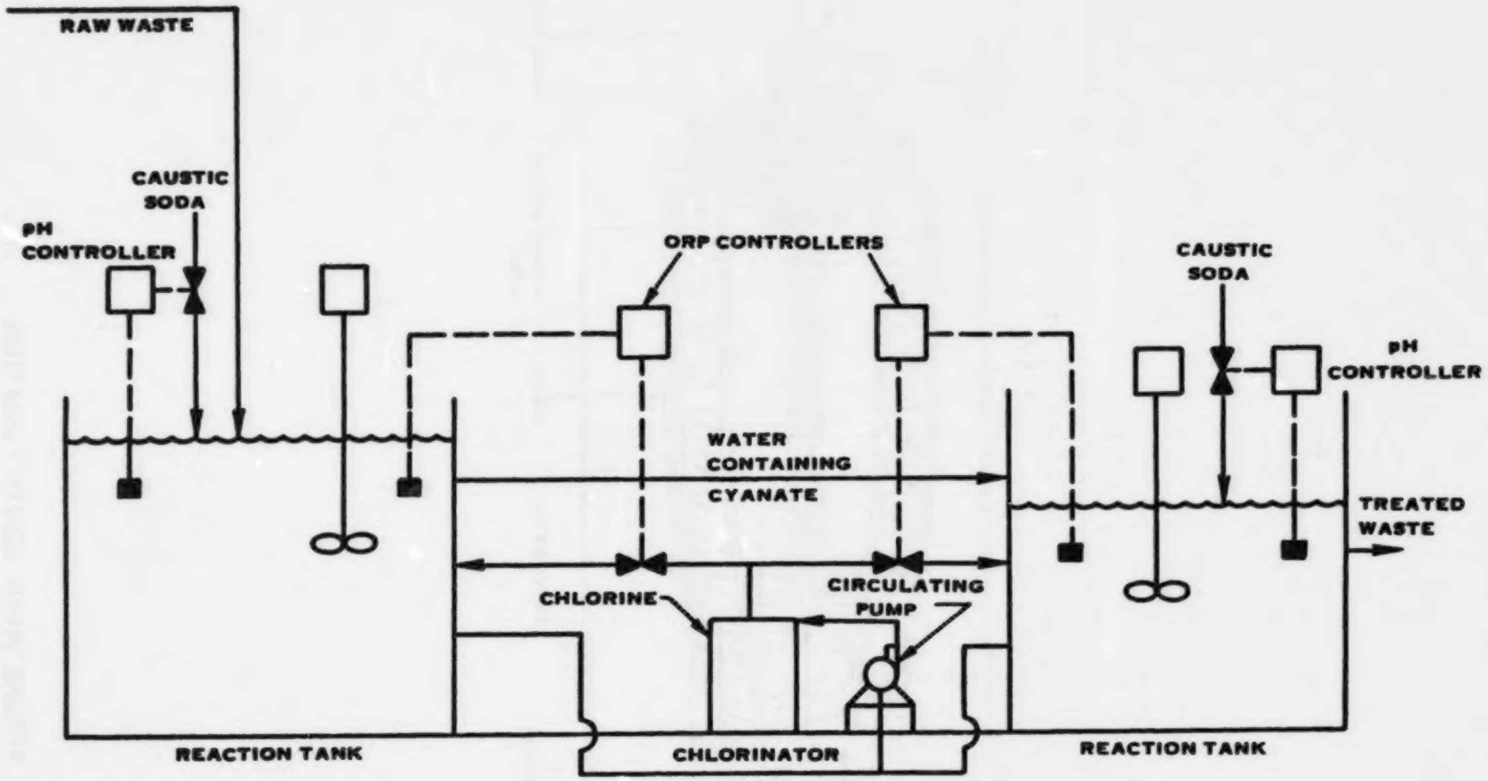

RAW WASTE
CAUSTIC SODA
pH CONTROLLER
ORP CONTROLLERS
CAUSTIC SODA
pH CONTROLLER
WATER CONTAINING CYANATE
TREATED WASTE
CHLORINE
CIRCULATING PUMP
REACTION TANK
CHLORINATOR
REACTION TANK

FIGURE VII-19. TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION

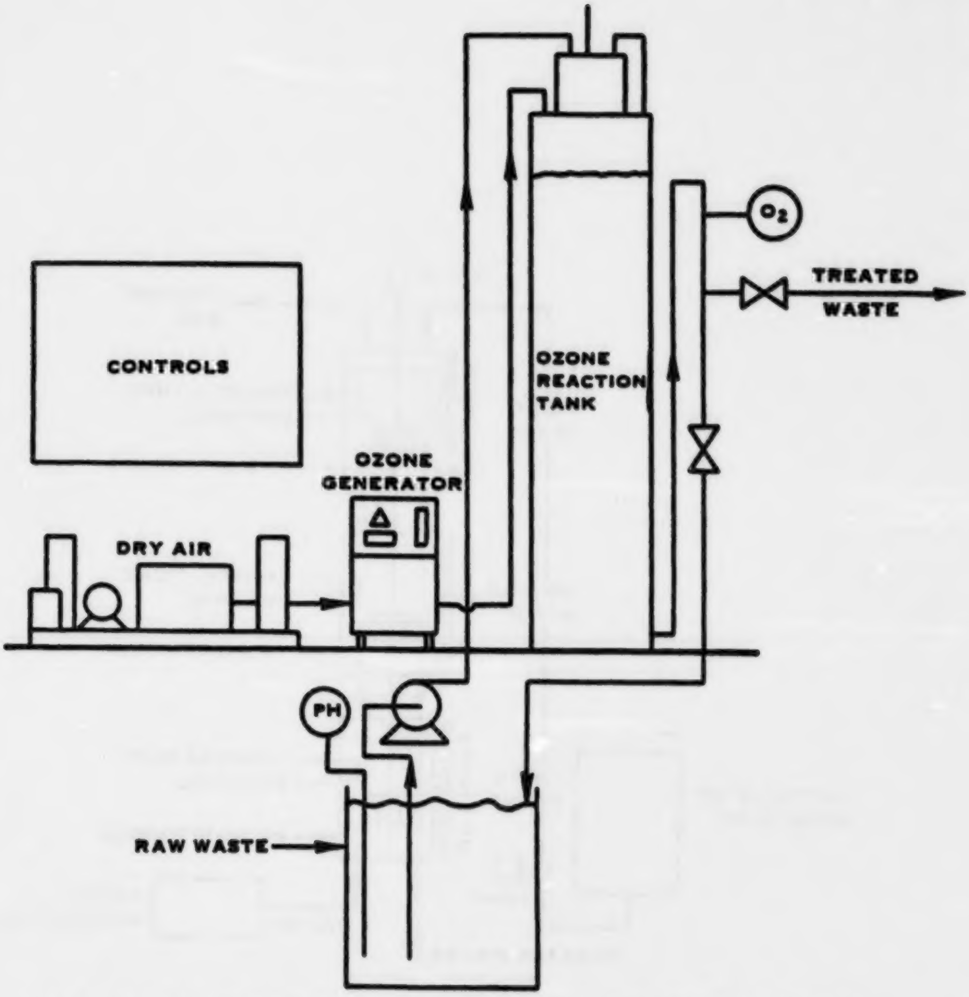

CONTROLS
OZONE GENERATOR
DRY AIR
OZONE REACTION TANK
O_2
TREATED WASTE
PH
RAW WASTE

FIGURE VII-20. TYPICAL OZONE PLANT FOR WASTE TREATMENT

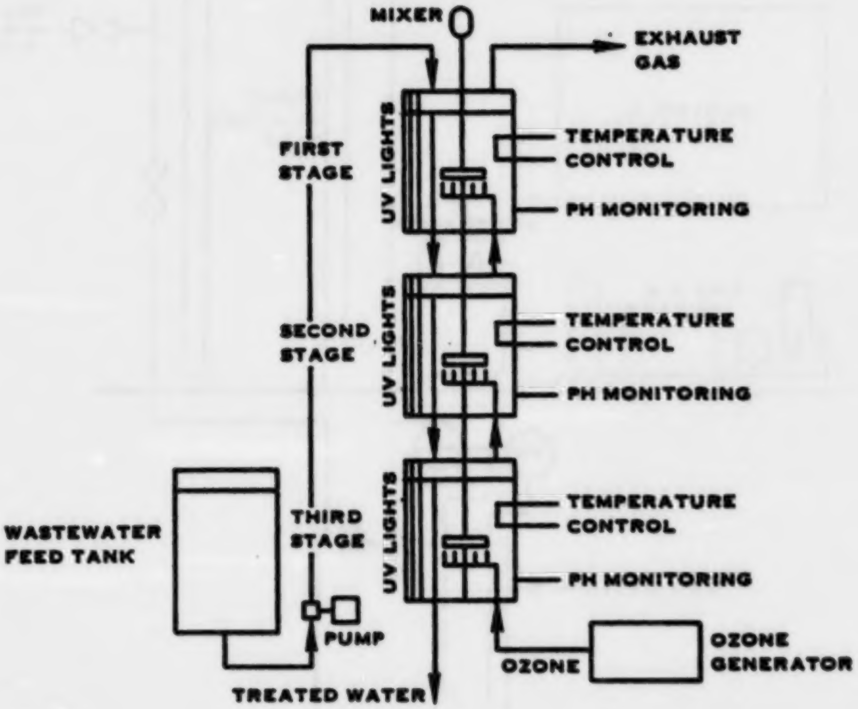
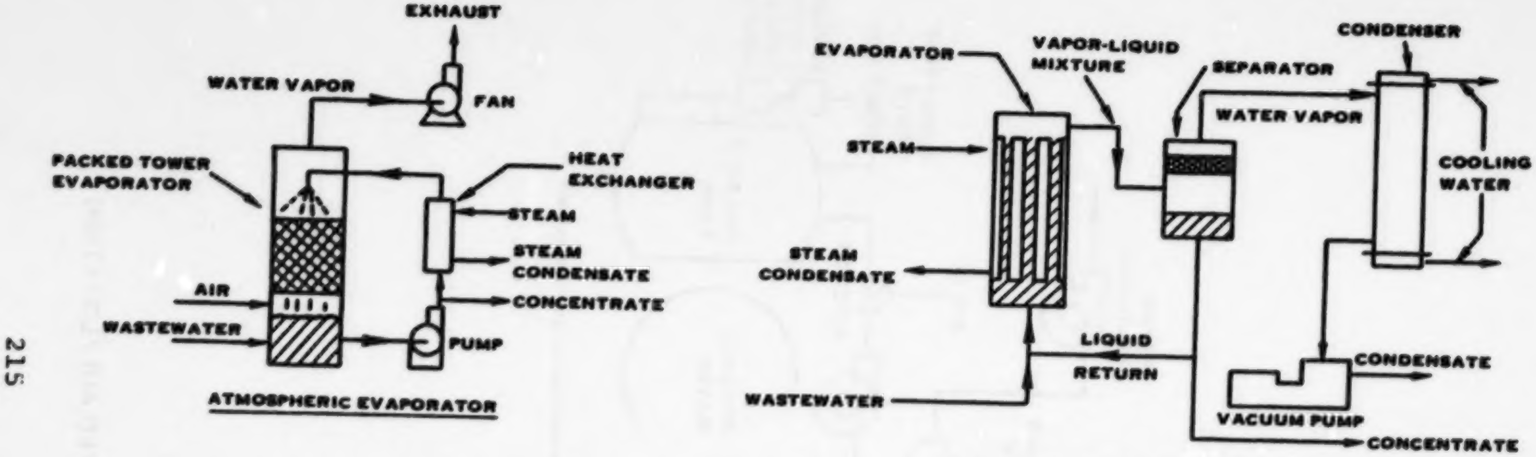
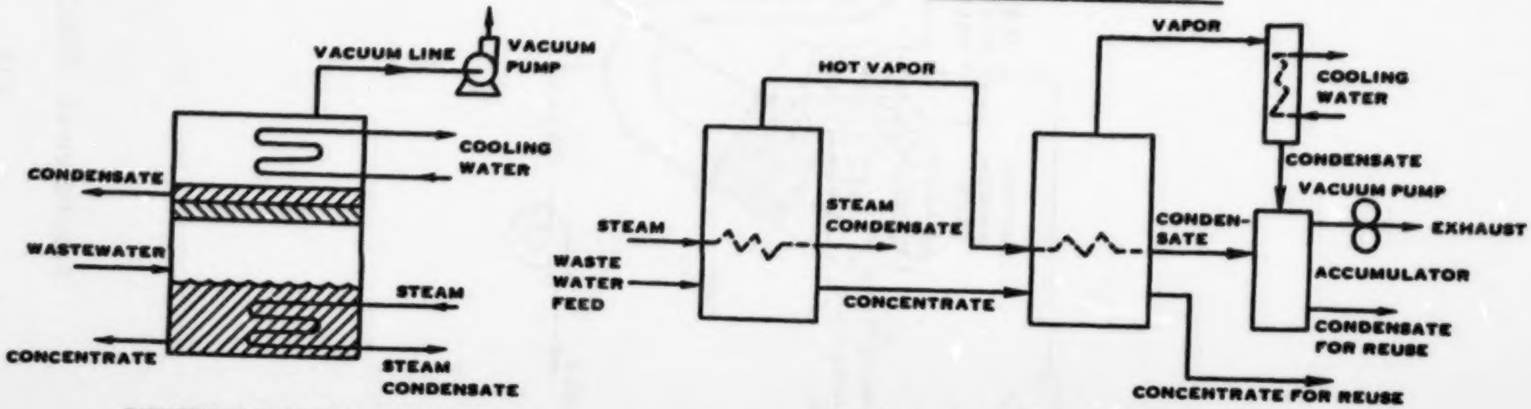

MIXER
EXHAUST GAS
FIRST STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
SECOND STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
WASTEWATER FEED TANK
THIRD STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
PUMP
OZONE
OZONE GENERATOR
TREATED WATER

FIGURE VII-21. UV/OZONATION


EXHAUST
WATER VAPOR
FAN
PACKED TOWER EVAPORATOR
HEAT EXCHANGER
STEAM
STEAM CONDENSATE
AIR
CONCENTRATE
WASTEWATER
PUMP
EVAPORATOR
VAPOR-LIQUID MIXTURE
SEPARATOR
CONDENSER
WATER VAPOR
STEAM
COOLING WATER
STEAM CONDENSATE
LIQUID RETURN
CONDENSATE
WASTEWATER
VACUUM PUMP
CONCENTRATE

ATMOSPHERIC EVAPORATOR

CLIMBING FILM EVAPORATOR


VACUUM LINE
VACUUM PUMP
COOLING WATER
CONDENSATE
WASTEWATER
STEAM
CONCENTRATE
STEAM CONDENSATE
VAPOR
HOT VAPOR
COOLING WATER
CONDENSATE
STEAM
STEAM CONDENSATE
CONDEN-SATE
VACUUM PUMP
EXHAUST
WASTE WATER FEED
ACCUMULATOR
CONCENTRATE
CONDENSATE FOR REUSE
CONCENTRATE FOR REUSE

SUBMERGED TUBE EVAPORATOR

DOUBLE-EFFECT EVAPORATOR

FIGURE VII-22. TYPES OF EVAPORATION EQUIPMENT

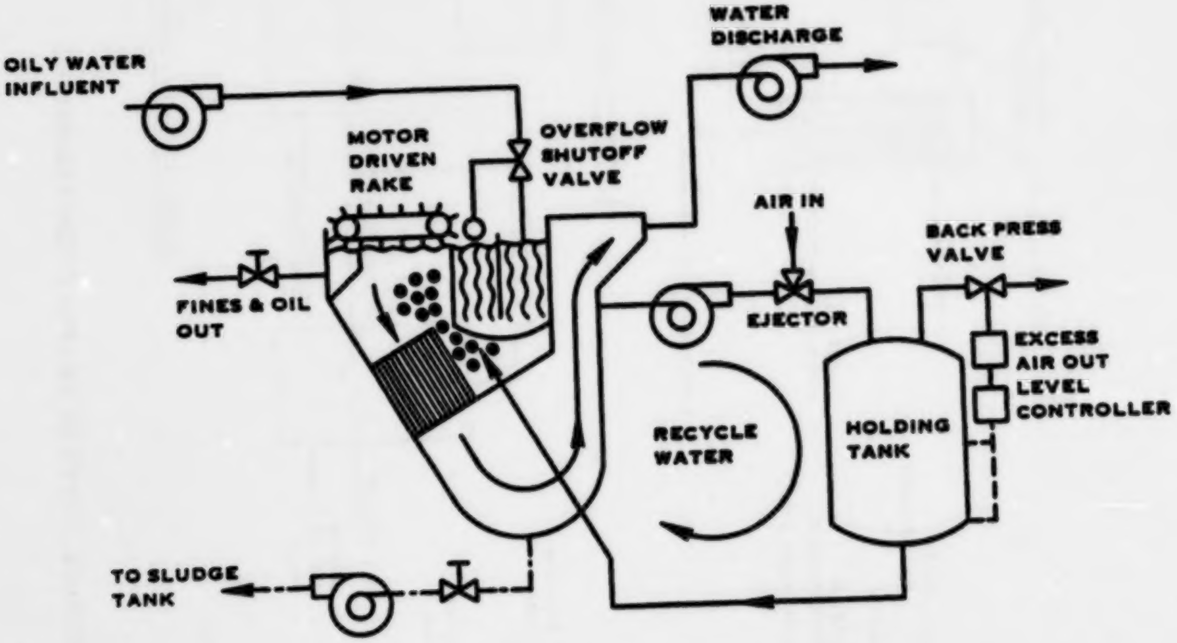
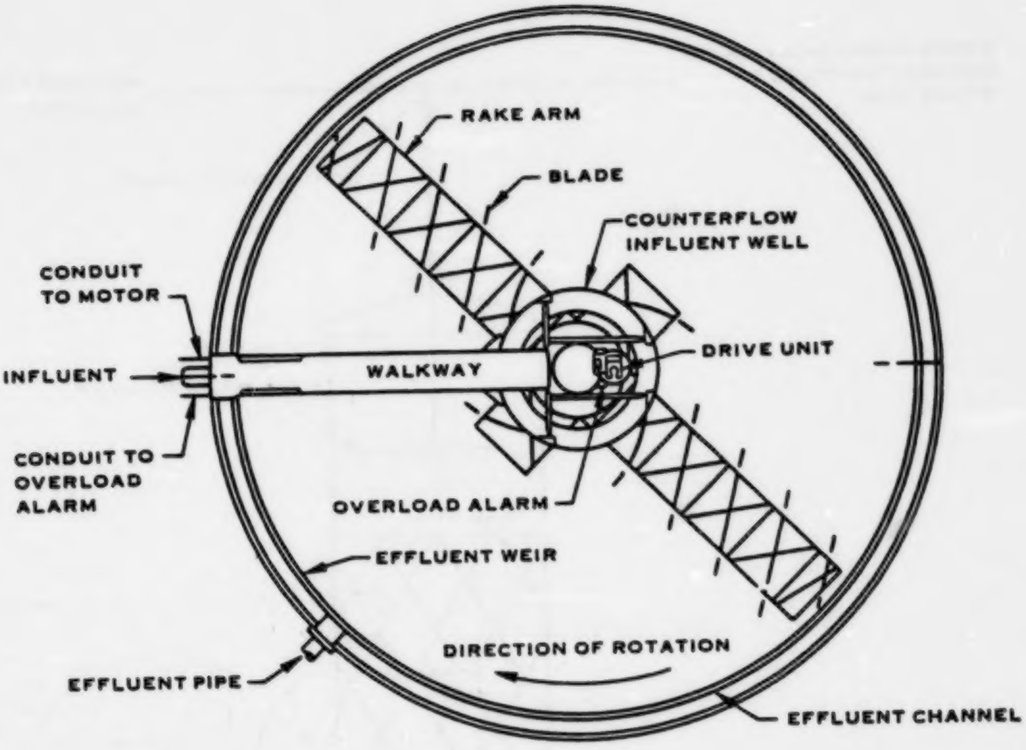

WATER DISCHARGE
OILY WATER INFLUENT
MOTOR DRIVEN RAKE
OVERFLOW SHUTOFF VALVE
AIR IN
BACK PRESS VALVE
FINES & OIL OUT
EJECTOR
EXCESS AIR OUT
LEVEL CONTROLLER
RECYCLE WATER
HOLDING TANK
TO SLUDGE TANK

FIGURE VII-23. DISSOLVED AIR FLOTATION


RAKE ARM
BLADE
COUNTERFLOW INFLUENT WELL
CONDUIT TO MOTOR
DRIVE UNIT
INFLUENT
WALKWAY
CONDUIT TO OVERLOAD ALARM
OVERLOAD ALARM
EFFLUENT WEIR
EFFLUENT PIPE
DIRECTION OF ROTATION
EFFLUENT CHANNEL

PLAN

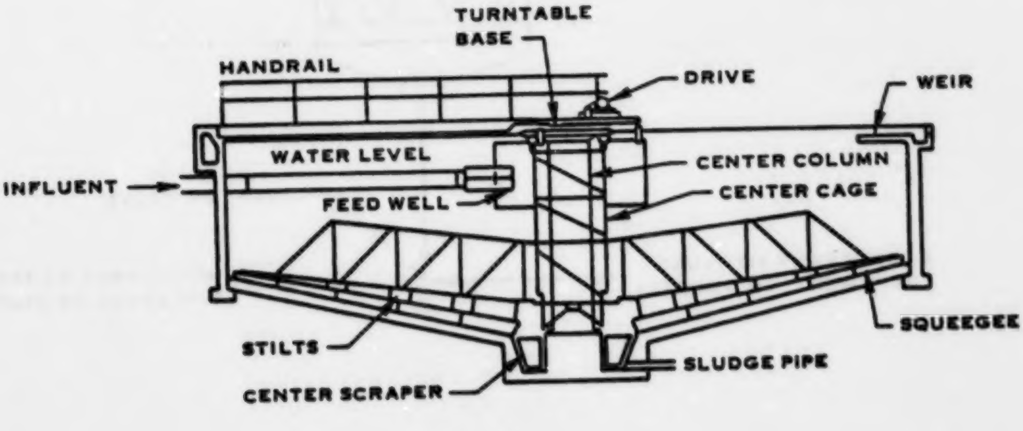

TURNTABLE BASE
HANDRAIL
DRIVE
WEIR
WATER LEVEL
CENTER COLUMN
INFLUENT
FEED WELL
CENTER CAGE
SQUEEGEE
STILTS
SLUDGE PIPE
CENTER SCRAPER

FIGURE VII-24. GRAVITY THICKENING

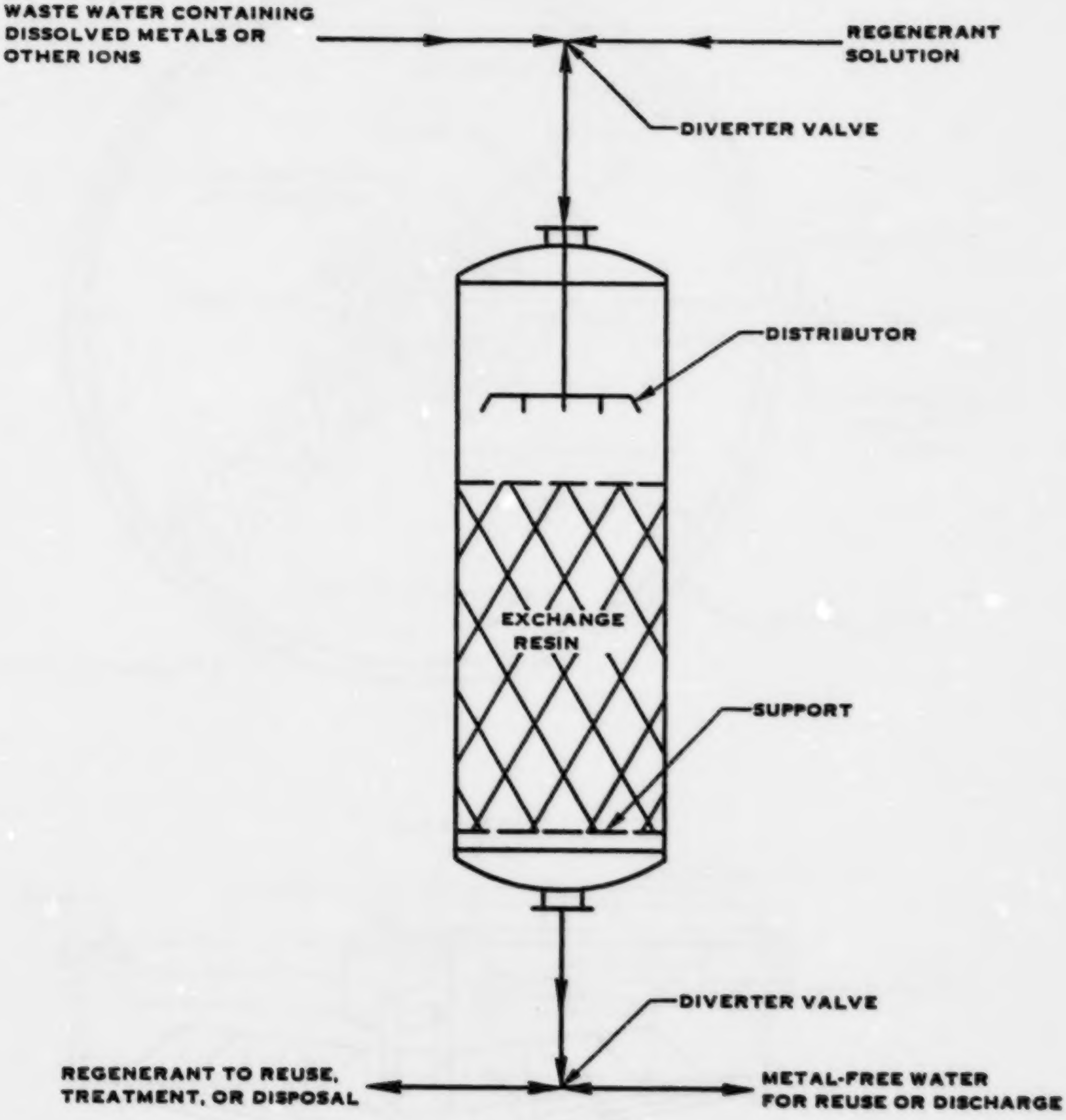

WASTE WATER CONTAINING DISSOLVED METALS OR OTHER IONS
REGENERANT SOLUTION
DIVERTER VALVE
DISTRIBUTOR
EXCHANGE RESIN
SUPPORT
DIVERTER VALVE
REGENERANT TO REUSE, TREATMENT, OR DISPOSAL
METAL-FREE WATER FOR REUSE OR DISCHARGE

FIGURE VII-25. ION EXCHANGE WITH REGENERATION

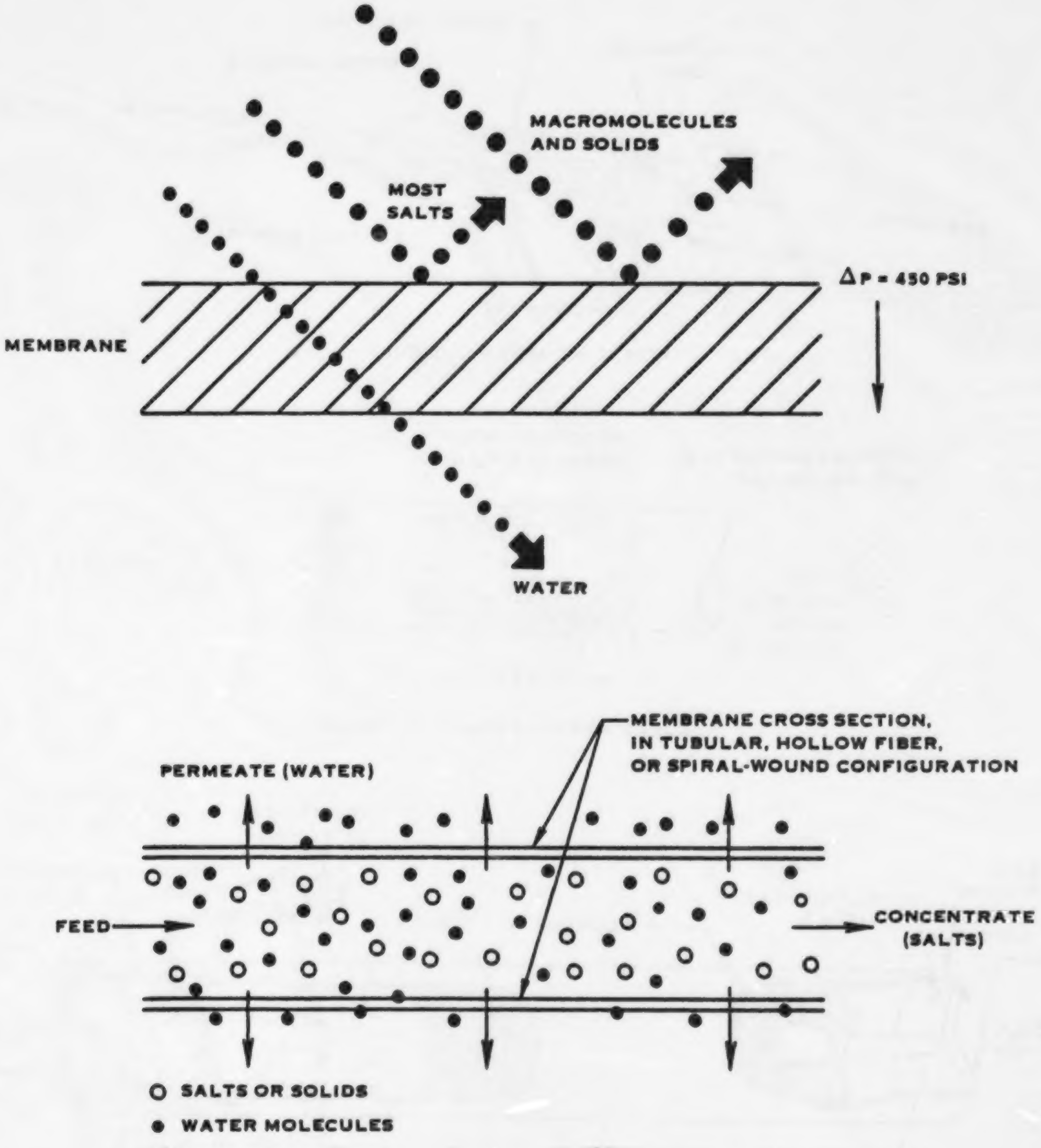
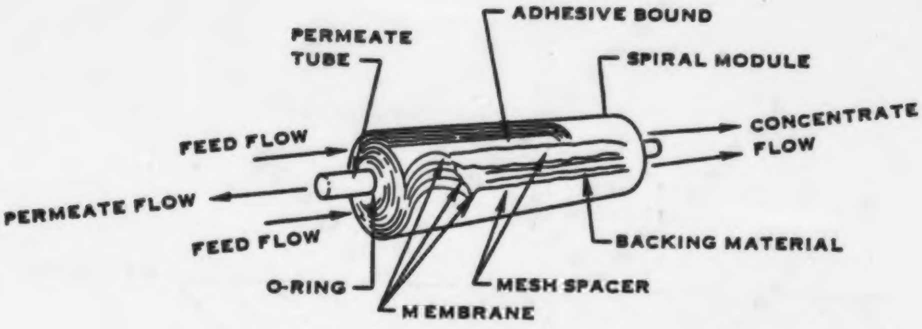
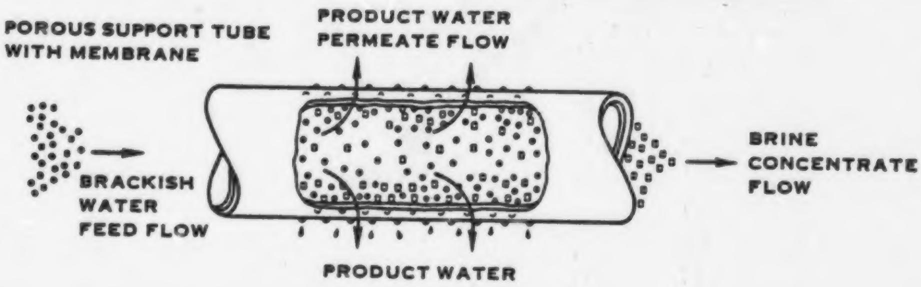

MACROMOLECULES AND SOLIDS
MOST SALTS
ΔP = 450 PSI
MEMBRANE
WATER
MEMBRANE CROSS SECTION, IN TUBULAR, HOLLOW FIBER, OR SPIRAL-WOUND CONFIGURATION
PERMEATE (WATER)
FEED
CONCENTRATE (SALTS)
○ SALTS OR SOLIDS
● WATER MOLECULES

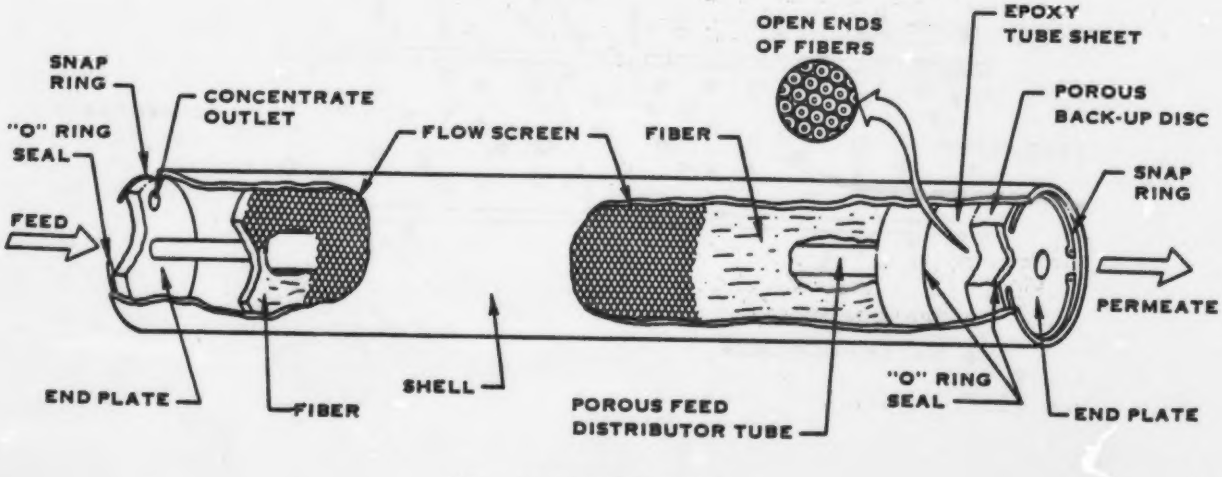
FIGURE VII-26. SIMPLIFIED REVERSE OSMOSIS SCHEMATIC


ADHESIVE BOUND
PERMEATE TUBE
SPIRAL MODULE
CONCENTRATE FLOW
FEED FLOW
PERMEATE FLOW
FEED FLOW
BACKING MATERIAL
O-RING
MESH SPACER
MEMBRANE

SPIRAL MEMBRANE MODULE

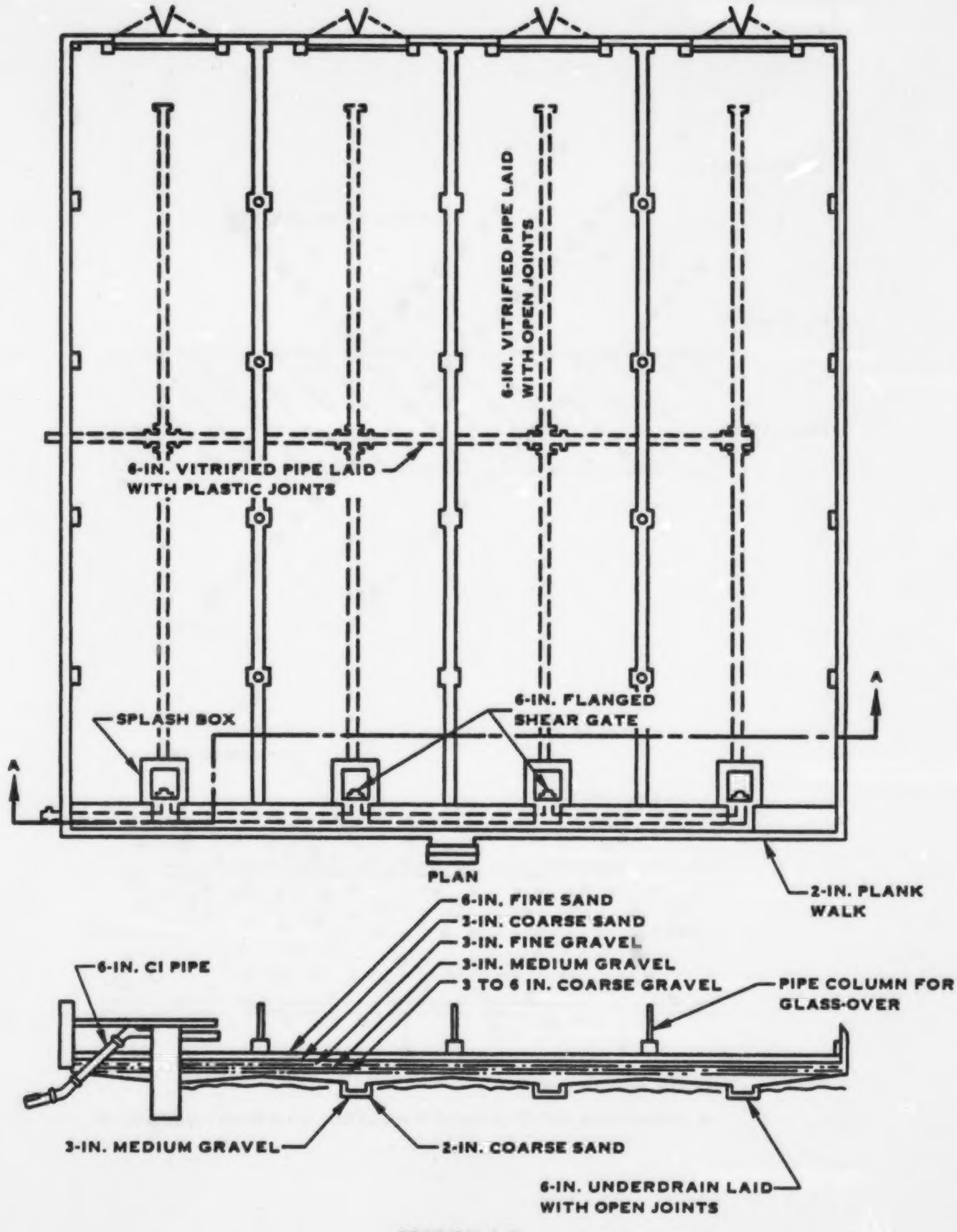

PRODUCT WATER PERMEATE FLOW
POROUS SUPPORT TUBE WITH MEMBRANE
BRINE CONCENTRATE FLOW
BRACKISH WATER FEED FLOW
PRODUCT WATER

TUBULAR REVERSE OSMOSIS MODULE


EPOXY TUBE SHEET
OPEN ENDS OF FIBERS
SNAP RING
CONCENTRATE OUTLET
POROUS BACK-UP DISC
"O" RING SEAL
FLOW SCREEN
FIBER
SNAP RING
FEED
PERMEATE
"O" RING SEAL
END PLATE
FIBER
SHELL
POROUS FEED DISTRIBUTOR TUBE
END PLATE

HOLLOW FIBER MODULE

FIGURE VII-27. REVERSE OSMOSIS MEMBRANE CONFIGURATIONS



6-IN. VITRIFIED PIPE LAID
WITH OPEN JOINTS
6-IN. VITRIFIED PIPE LAID
WITH PLASTIC JOINTS
SPLASH BOX
6-IN. FLANGED
SHEAR GATE
A
A
PLAN
2-IN. PLANK
WALK
6-IN. FINE SAND
3-IN. COARSE SAND
3-IN. FINE GRAVEL
3-IN. MEDIUM GRAVEL
3 TO 6 IN. COARSE GRAVEL
6-IN. CI PIPE
PIPE COLUMN FOR
GLASS-OVER
3-IN. MEDIUM GRAVEL
2-IN. COARSE SAND
6-IN. UNDERDRAIN LAID
WITH OPEN JOINTS
SECTION A-A

FIGURE VII-28. SLUDGE DRYING BED

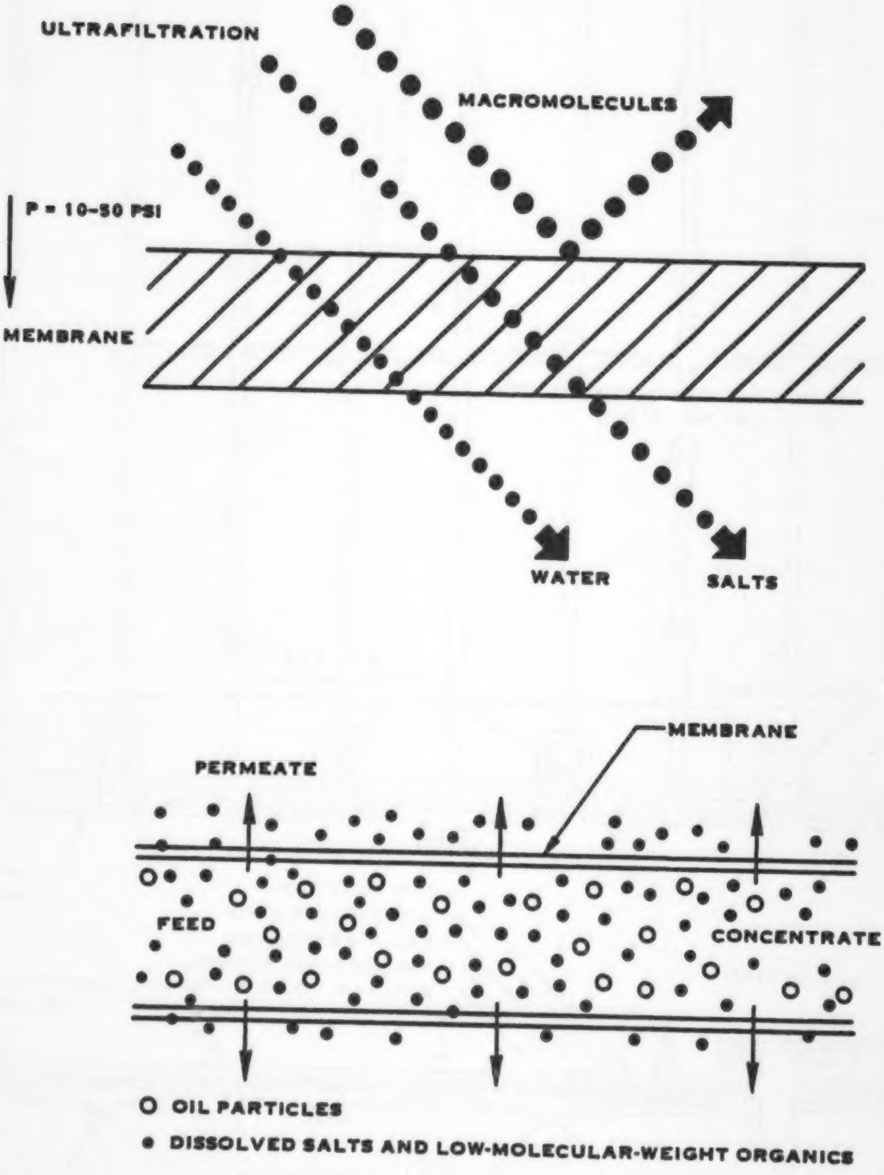

ULTRAFILTRATION
MACROMOLECULES
P = 10-50 PSI
MEMBRANE
WATER
SALTS
MEMBRANE
PERMEATE
FEED
CONCENTRATE
O OIL PARTICLES
• DISSOLVED SALTS AND LOW-MOLECULAR-WEIGHT ORGANICS

FIGURE VII-29. SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC

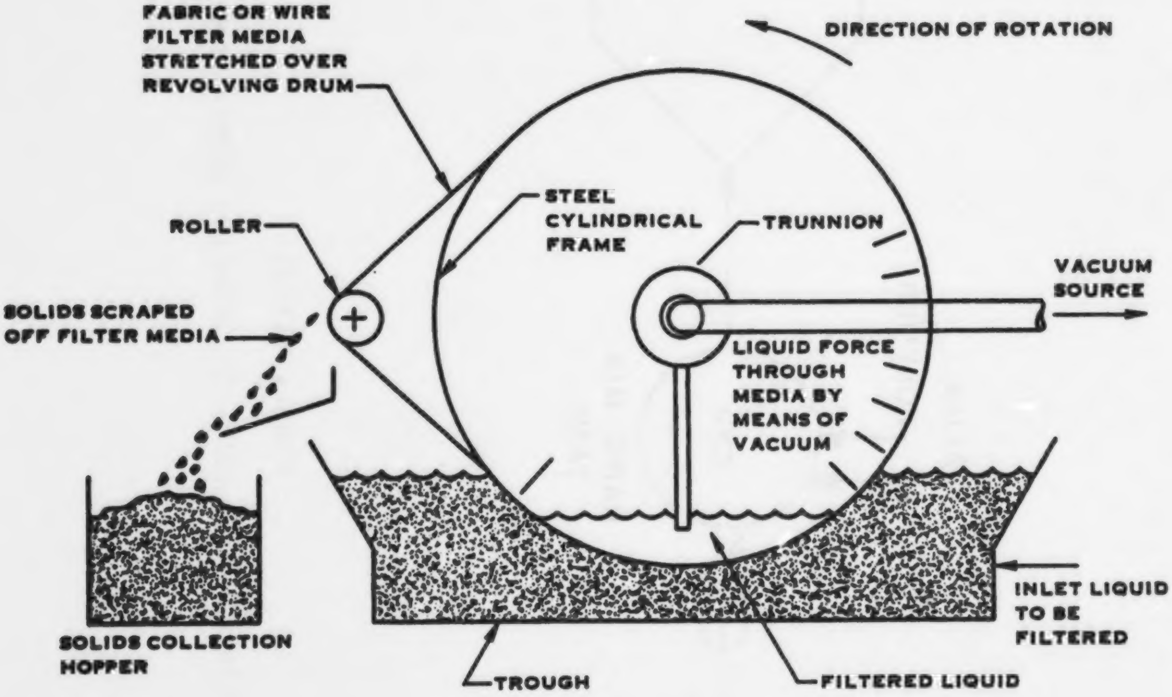

FABRIC OR WIRE FILTER MEDIA STRETCHED OVER REVOLVING DRUM
DIRECTION OF ROTATION
STEEL CYLINDRICAL FRAME
ROLLER
TRUNNION
VACUUM SOURCE
SOLIDS SCRAPED OFF FILTER MEDIA
LIQUID FORCE THROUGH MEDIA BY MEANS OF VACUUM
INLET LIQUID TO BE FILTERED
SOLIDS COLLECTION HOPPER
TROUGH
FILTERED LIQUID

FIGURE VII-30. VACUUM FILTRATION

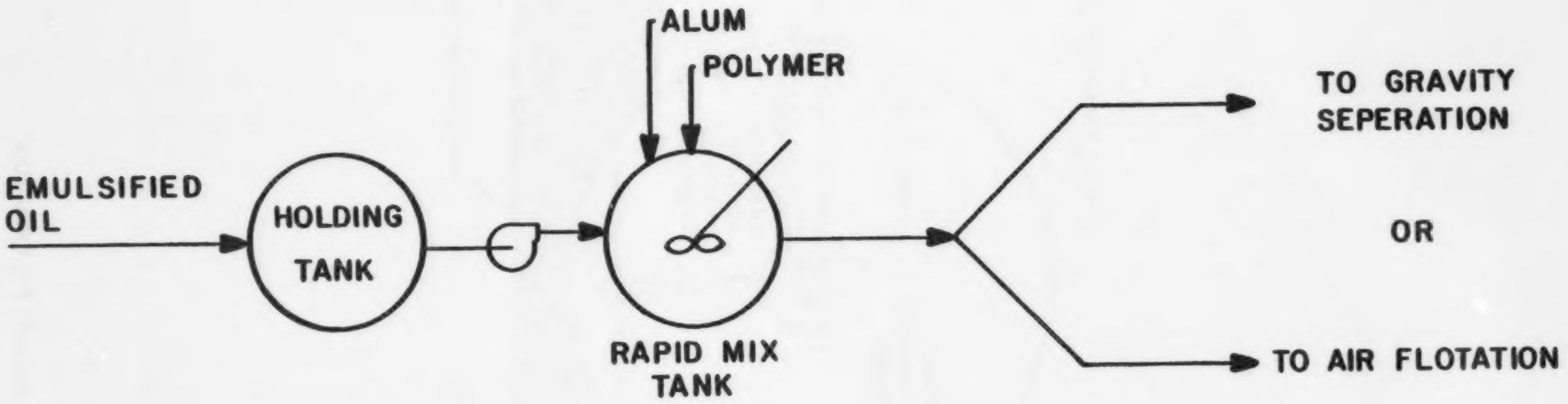

ALUM
POLYMER
EMULSIFIED OIL
HOLDING TANK
RAPID MIX TANK
TO GRAVITY SEPERATION
OR
TO AIR FLOTATION

Figure VII-31

FLOW DIAGRAM FOR EMULSION BREAKING WITH CHEMICALS

SECTION VIII

COST, ENERGY, AND NONWATER QUALITY ASPECTS

This section presents estimates of the costs of implementing the major wastewater treatment and control technologies described in Section VII. These cost estimates, together with the estimated pollutant reduction performance for each treatment and control option presented in Sections IX, X, XI, and XII provide a basis for evaluating the options presented and identification of the best practicable control technology currently available (BPT), best available technology economically achievable (BAT), best demonstrated technology (BDT), and the appropriate technology for pretreatment. The cost estimates also provide the basis for the determination of the probable economic impact on the canmaking subcategory of regulation at different pollutant discharge levels. In addition, this section addresses nonwater quality environmental impacts of wastewater treatment and control alternatives, including air pollution, noise pollution, solid wastes, and energy requirements.

Briefly, the approach taken to develop capital and operating costs was to identify a normal canmaking line and its water use, discharge rate and characteristics. These values were used as input to a computer cost estimation model which is discussed below. For certain modules, the Agency's existing cost data base was used to develop costs. The costs for the three-line plant were extrapolated to different size plants by applying the so-called "six tenths power rule." This process was employed for each existing source and new source treatment option.

COST ESTIMATION METHODOLOGY

For the canmaking subcategory, cost estimation is accomplished for most modules using a computer model which accepts inputs specifying the treatment system to be estimated, chemical characteristics of the raw waste streams, flow rates and treatment system entry points of these streams, and operating schedules. This model utilizes a computer-aided design of a wastewater treatment system containing modules that are configured to reflect the appropriate equipment at an individual plant. The model designs each module and then executes a costing routine that contains the cost data for each module. The capital and annual costs from the costing routine are combined with capital and annual costs for the other modules to yield the total costs for that regulatory option. The process is then repeated for each regulatory option.

Each module was developed by coupling theoretical design information from the technical literature with actual design data from operating plants. This permits the most representative design approach possible to be used, which is a very important element of accurately estimating costs. The fundamental units for design and costing are not the modules themselves but the components within each module, e.g., the lime feed system within the chemical precipitation module. This is a significant feature of this model for two reasons. First, it does not limit the model to certain fixed relationships between various components of each module. For instance, cost data for chemical precipitation systems are typically presented graphically as a family of curves with lime (or other alkali) dosage as a parametric function. The model, however, sizes the lime feed system as a function of the required mass addition rate (lb/hr) of lime. The model thus selects a feed system specifically designed for that plant. Second, this approach more closely reflects the way a plant would actually design and purchase its equipment. The resulting costs are thus more closely tied to the actual costs that would be incurred by the facility.

Overall Structure

The cost estimation model comprises two main parts: a material design portion and a costing portion. The material design portion uses input provided by the user to calculate design parameters for each module included in the treatment system. The design parameters are then used as input to the costing routine, which contains cost equations for each discrete component in the system. The structure of the program is such that the entire system is designed before any costs are estimated.

Throughout the program, the following pollutants or parameters are tracked:

- Flow,
- Total suspended solids,
- pH,
- Acidity,
- Cadmium,
- Chromium,
- Copper,
- Lead,

- Nickel,
- Zinc,
- Iron,
- Aluminum,
- Manganese, and
- Hexavalent chromium.

The overall logic flow of the computer programs is depicted in Figure VIII-1 (page 246). First, constants are initialized and certain variables such as the modules to be included, the system configuration, and plant and wastewater flows, compositions, and entry points are specified by the user. Each module is designed utilizing the appropriate flow and composition data for influent streams. The design values are transmitted to the cost routine. The appropriate cost equations are applied, and the module costs and system costs are computed. Figures VIII-2 and VIII-3 (pages 247 and 248) depict the logic flow diagrams in more detail for the two major segments of the program.

System Input Data

Several data inputs are required to run the computer model. First, the treatment modules to be costed and their sequence must be specified. Next, information on hours of operation per day and number of days of operation per year is required. The flow values and characteristics must be specified for each wastewater stream entering the treatment system. The values will dictate the size and other parameters of components to be included.

These inputs are derived from actual data if costs are sought for actual plants. Where costs are developed for representative plants, flows and concentrations are derived from aggregated data. For development of costs for the canmaking industry, data from Section V were used; these data are also summarized later in this section.

Model Results

For a given plant, the model will generate comprehensive material balances for each parameter tracked at any point in the system. It will also summarize design values for key equipment in each treatment module, and provide a tabulation of costs for each element in each module, module summaries, total equipment costs, and system capital and annual costs.

GENERAL COST FACTORS

Dollar Base - All costs are adjusted to first quarter 1982 dollars.

Cost Update Factors

Investment - Investment costs were updated using the EPA-Sewage Treatment Plant Construction Cost Index. The value of this index for the first quarter of 1982 is 414.0.

Operation and Maintenance Labor - The ENR Skilled Labor Wage Index is used to update the portion of O&M costs attributable to labor. The March 1982 value is 325.

Maintenance Materials - The producer price index published by the Department of Labor, Bureau of Statistics is used. The March 1982 value of this index is 276.5.

Chemicals - The Chemical Engineering Producer Price Index for industrial chemicals is used. This index is published biweekly in *Chemical Engineering* magazine. The March 1982 value of this index is 362.6.

Energy - Updating power costs is accomplished by using the price for the desired date for electricity and multiplying it by the energy requirements for the module in kwhr equivalents.

Capital Recovery

Capital recovery costs for recovery of committed capital may be calculated by using a capital recovery factor, given by the following equation:

$$CRF = i + \frac{i}{(1 + i)^n - 1}$$

where CRF = capital recovery factor,
i = interest rate, and
n = period of amortization.

For this analysis, an interest rate of 12 percent and a period of 10 years were used. This yields a capital recovery factor of 0.17698. This value is multiplied by the total capital investment to give the annual amortization charge.

Annual Costs

Labor - A base labor rate for skilled labor of $9.00 per hour was used. To account for supervisory personnel, 15 percent of the labor rate was included. Plant overhead at 100 percent of the combined base and supervisory labor charges is also included.

The resulting composite labor rate used in this study is $21.00 per hour.

Operating Schedule - Two hundred and fifty days per year, 24 hours per day was assumed.

Energy - An electrical cost of 4.83 cents/kwh (March, 1982) was assumed, based on the industrial cost derived from DOE's Monthly Energy Review.

System Costs

Engineering - This was assumed to be 15 percent of the total module cost.

Contractor's Fee - This was assumed to be 10 percent of the summed module cost.

Contingency - This was assumed at 10 percent of the summed module cost.

TECHNOLOGY BASIS FOR COST ESTIMATION

Four options for existing sources and two options for new sources were identified as the treatment alternatives for the canmaking subcategory. The technologies used, which were described in detail in Section VII, include:

- Countercurrent rinsing,
- Equalization,
- Chemical emulsion breaking,
- Dissolved air flotation,
- Chemical precipitation-sedimentation,
- Vacuum filtration,
- Multimedia filtration, and
- Ultrafiltration.

Where necessary, the following technologies are also available:

- Cyanide precipitation, and

- Chromium reduction.

The cost elements of each technology are discussed below.

Countercurrent Rinsing

This technology is applied to product rinsing operations. It involves a number of spray rinse stages, with product and rinse water moving in opposite directions (more detail may be found in Section VII). This allows for significantly reduced flow over single stage rinsing by contacting the most contaminated rinse water with the incoming product.

The countercurrent system for existing plants in this subcategory was designed assuming that a tank for single stage rinse was already installed. The tank was converted to a two stage countercurrent operation by installing a baffle in the tank, recycle piping, an additional set of stainless steel spray nozzles, and an additional pump. The baffle was sized based on a 1.2 x 2.4 x 1.2 meter (4 x 8 x 4 foot) tank using rubber-lined carbon steel. Nine meters (30 feet) of rubber-lined steel pipe, 14 additional nozzles, and a centrifugal pump rated at 1,814 lpm (480 gpm) were assumed to be required. Installation of the purchased equipment cost at 50 percent, and engineering, contractor's fees, and contingencies at 35 percent of the installed equipment cost were added, as was a retrofit allowance at 15 percent of the total.

Operation and maintenance costs were calculated assuming 300 hours per year of labor for the tank, and maintenance materials were estimated at 2 percent of the capital cost.

Equalization

The computer cost estimation model was used for this module. The equalization tanks are of the vertical steel type with capacities which vary as a function of flow rate. The detention time is eight hours and the excess capacity is 20 percent. The tanks are fitted with agitators with a horsepower requirement of 0.006 kw/1,000 liters (.03 hp/1,000 gallons) of capacity to prevent sedimentation. A control system, valves, a pump, and piping are also included.

The capital and annual costs are presented in Figure VIII-4 (page 249).

Chemical Emulsion Breaking

Chemical emulsion breaking involves the separation of relatively stable oil-water mixtures by addition of certain chemicals, in this case, alum and polymer. To determine the capital and annual costs, 400 mg/l of alum and 10 mg/l of polymer are assumed to be added to waste streams containing emulsified oils. The equipment included in the capital and annual costs are as follows:

- Chemical feed system
    1. Storage units
    2. Dilution tanks
    3. Conveyors and chemical feed lines
    4. Chemical feed pumps

- Rapid mix tank
    1. Tank
    2. Mixer
    3. Motor drive unit

- Skimming
    1. Gravity separation basin
    2. Surface skimmer
    3. Bottom sludge scraper

Costs were derived based on a composite of various systems which included the above equipment. Alum and polymer costs were obtained from vendors: dry alum at $0.33 per kg ($0.15 per pound) and polymer at $6.60 per kg ($3.00 per pound). Energy requirements were also drawn from various literature sources and are included in the annual costs. The costs were updated to first quarter, 1982.

The capital and annual costs are presented in Figure VIII-5 (page 250).

Dissolved Air Flotation

Dissolved air flotation (DAF) can be used by itself, in conjunction with gravity separation for the removal of free oil, or also in conjunction with coagulant and flocculant addition to increase oil removal efficiency. The capital and annual costs are based on the dissolved air flotation unit only; other systems, such as flocculant addition, may be added in separately.

The equipment used to develop capital and annual costs for the DAF system is as follows:

- Flotation unit
- Surface skimmer
- Bottom sludge scraper
- Pressurization unit

- Recycle pump
- Electrical and instrumentation
- Concrete pad, 1 ft. thick

Basic assumptions include a hydraulic loading of 0.70 lpm/m^2 (2 gpm/ft^2) and a recycle ratio of 30 percent. All costs and energy requirements were derived as composites of various systems presented in the literature. Operational and maintenance labor are estimated to range from 700 hrs/yr at 113,000 lpd (30,000 gpd) to 1,800 hrs/yr at 3.78 x 10^7 lpd (10 mgd). Energy requirements are estimated to range from 54,000 Kw-hr/yr at 113,000 lpd (30,000 gpd) to 3,500,000 kw/hr/yr at 3.78 x 10^7 lpd (10 mgd). Below 113,000 lpd (30,000 gpd) flow rate, energy requirements are considered to be constant.

The capital and annual costs for this technology are presented in Figure VIII-6 (page 251).

Chemical Precipitation

Quicklime (CaO) or hydrated lime [$Ca(OH)_2$] can be used to precipitate toxic and other metals. Hydrated lime is commonly used for wastewaters with low lime requirements since the use of slakers, required for quicklime usage, is practical only for large-volume application of lime. Due to the low lime dosage requirements in this industry, hydrated lime is used for costing. The lime dosage requirements were determined by the model using specific influent characteristics and flow derived from wastewater data for representative canmaking operations.

The following equipment were included in the determination of capital and annual costs based on continuous operation:

- Lime feed system
    1. Storage units (sized for 30-day storage)
    2. Dilution tanks (five minutes average retention)
    3. Feed pumps

- Rapid mix tank (detention time of five minutes; mixer velocity gradient is 300/sec)
- Clarifier (overflow rate is 7.3 lph/m^2 (20.8 gph/ft^2); underflow solids is 3 percent)
    1. Sludge rakes
    2. Skimmer
    3. Weirs

- Sludge pump

The model assumes that a 25 percent excess of lime is used, that the final pH is 9.0, and the effluent pollutant concentrations are based on the Agency's combined data base lime precipitation treatability values.

Batch operation assumes a two fiberglass or steel tank system (if additional capacity is required, tanks are added in pairs) with one lime feed system (includes one agitated mixing tank with hydrated lime added manually in 22.7 kg (50 lb) bags for every two tanks), a sludge pump for up to four tanks, and a simple control system. A lime storage shed is included for lime addition rates ≥ 90.7 kg/batch (200 lbs/batch).

O&M costs for the continuous system are for operating and maintenance labor for the clarifier and lime feed system, and the cost for chemicals, maintenance materials, and energy. For the batch mode, operational labor is assumed at one half hour per batch for lime addition up to 90.7 kg/batch (200 lbs/batch) and one hour per batch for additional rates above 90.7 kkg/batch (200 lbs/batch). Maintenance labor is constant for the batch system at 52 hours per year (one hour/week). Lime is $47.30/kkg ($43/ton) in 22.7 kg (50 lb) bags and energy requirements and maintenance materials are negligible.

The operating mode is selected based on an annualized cost comparison assuming a 1,200 mg/l lime dosage. The capital and annual costs for this technology are presented in Figure VIII-7 (page 252).

Vacuum Filtration

The underflow from the clarifier is routed to a rotary precoat vacuum filter, which dewaters the mostly hydroxide sludge (it also includes calcium fluoride precipitate) to a cake of 20 percent dry solids. The filtrate is recycled to the rapid mix tank as seed material for sludge formation.

The capital costs for the vacuum filter include the following:

- Vacuum filter with precoat but no sludge conditioning
- Housing
- Pump

The yield from the filter is assumed at 0.126 $kg/hr/m^2$ (3 $lb/hr/ft^2$) with a solids capture of 95 percent. Housing the filter, which approximately doubles the capital cost of the module, is required for this technology. The capital and annual costs for this technology are presented in Figure VIII-8 (page 253).

Multimedia Filtration

Multimedia filtration is used as a wastewater treatment polishing device to remove suspended solids not removed in previous treatment processes. The filter beds consist of graded layers of gravel, coarse anthracite coal, and fine sand. The equipment used to determine capital and annual costs are as follows:

- Influent storage tank sized for one backwash volume
- Gravity flow, vertical steel cylindrical filters with media (anthracite, sand, and garnet)
- Backwash tank sized for one backwash volume
- Backwash pump to provide necessary flow and head for backwash operations
- Piping, valves, and a control system

The hydraulic loading rate is 63.2 lph/m^2 (180 gph/ft^2) and the backwash loading is 252.8 lph/m^2 (720 gph/ft^2). The filter is backwashed once per 24 hours for 10 minutes. The backwash volume is provided from the stored filtrate. The backwash stream is recycled to the clarifier. The capital and annual costs for this technology are presented in Figure VIII-9 (page 254).

Effluent pollutant concentrations are based on the Agency's combined data base for treatability of pollutants by filtration technology.

Ultrafiltration

The ultrafiltration process employs a semipermeable polymeric membrane to remove colloidal material from a wastewater. In contrast to multimedia filtration, ultrafiltration does not operate intermittently, i.e., retained materials are continuously rather than periodically removed.

The equipment costed for this process includes:

- Membrane modules
- Equalization tank
- Process tank
- Feed pump
- Recirculation pump
- Piping
- Electrical and instrumentation

A flux rate of 0.51 lph/m^2 (1.46 gph/ft^2) is applied in the tubular module.

Operation and maintenance labor is assumed to be negligible for this module. Chemical costs include cleaning solution, caustic, and acid for pH control. Maintenance materials primarily include replacement of filter membranes, which are estimated to have a two year life. The capital and annual costs for this technology are presented in Figure VIII-10 (page 255).

Cyanide Precipitation

Canmaking facilities that generate wastewaters with significant concentrations of cyanide can reduce these by application of cyanide precipitation technology. Cyanide is reacted with ferrous sulfate at pH 9.0 to form a ferrous cyanide complex. This complex is precipitated by additional ferric ions to form primarily a deep blue precipitate, $Fe_4\ (FeCN_6)_3$.

This continuous system, which closely resembles a conventional chemical precipitation operation, includes chemical feed equipment for sodium hydroxide and ferrous sulfate addition, a rapid mix tank, agitator, control system, clarifier and pumps.

The $FeSO_4\ 7H_2O$ dosage is assumed at 11 times the stoichiometric requirement. The clarifier overflow rate was assumed to be 7.3 lph/m^2 (20.8 gph/ft^2), with an underflow solids concentration of 3 percent. A portion of the underflow stream is recycled to the rapid mix tank to provide seed sludge.

Annual costs for cyanide precipitation include:

(1) Ferrous sulfate feed system

--operating labor at 1.1 hr/1,000 kg per feeder
--maintenance labor at 32 hrs/yr
--maintenance materials at 3 percent of the manufactured equipment cost
--electrical requirements for mixers, feeder operation, building heating and lighting

(2) NaOH feed system

--operating labor at 190 hrs/yr per feeder
--maintenance labor at 8 hrs/yr
--maintenance materials at 3 percent of the manufactured equipment cost
--electrical requirements for feeder, mixer, and pump

(3) Rapid mix tank

--operation and maintenance labor at 120 hrs/yr
--electrical requirements for agitator

(4) Clarifier

- --operation and maintenance labor varies from 150 hrs/yr at 9.1 m (30 ft) diameter to 310 hrs/yr for 35 m (115 ft) diameter
- --maintenance materials include parts required for drive mechanism and weirs
- --energy requirements for motor size and torque requirements for hydroxide sludges

Costs for treatment chemicals are determined from cyanide concentration, pH, metals concentrations, and flow rate of the raw waste streams.

The capital and annual costs for this technology are displayed in Figure VIII-11 (page 256).

Chromium Reduction

This technology can be applied to waste streams containing significant concentrations of hexavalent chromium. Chromium in this form will not precipitate until it has been reduced to the trivalent form. The waste stream is treated by addition of acid and gaseous SO_2 dissolved in water in an agitated reaction vessel. The SO_2 is oxidized to sulfate while reducing the chromium. The equipment required for this continuous stream includes an SO_2 feed system (sulfonator), an H_2SO_4 feed system, a reactor vessel and agitator, and a pump. The reaction pH is 2.5 and the SO_2 dosage is a function of the influent loading of hexavalent chromium. A conventional sulfonator is used to meter SO_2 to the reaction vessel. The mixer velocity gradient is 100/sec.

Annual costs are as follows:

(1) SO_2 feed system

- -- SO_2 cost at \$0.11/kg (\$0.25/lb)

- --operation and maintenance labor requirements vary from 437 hrs/yr at 4.5 kg SO_2/day (10 lbs SO_2/day) to 5,440 hrs/yr at 4,540 kg SO_2/day (10,000 lbs SO_2/day)
- --energy requirements at 570 kwh/yr at 4.5 kg SO_2/day (10 lbs SO_2/day) to 31,000 kwh/yr at 4,540 kg SO_2/day (10,000 lbs SO_2/day)

(2) H_2SO_4 feed system

- --operating and maintenance labor at 72 hrs/yr at 37.8 lpd (10 gpd) of 93 percent H_2SO_4 to 200 hrs/yr at 3,780 lpd (1,000 gpd)

--maintenance materials at 3 percent of the equipment cost
--energy requirements for metering pump and storage heating and lighting

(3) Reactor vessel and agitator

--operation and maintenance labor at 120 hrs/yr
--electrical requirements for agitator

The capital and annual costs for this technology are displayed in Figure VIII-12 (page 257).

SYSTEM COST DEVELOPMENT

Existing Sources

To compile capital and annual costs for the canmaking subcategory, the computer cost estimation model was utilized for the following modules:

- Equalization,

- Chemical precipitation,

- Vacuum filtration, and

- Multimedia filtration.

The design and costing for the remaining modules have not yet been incorporated into the cost estimation model. Consequently, the Agency's existing cost data base for industries similar to the canmaking subcategory was utilized to develop the costs for these modules.

The cost evaluation was based on the identification of a "normal" existing plant, which was postulated to operate three normal processing lines. For currently existing facilities, the water discharged is equal to 176 liters per thousand cans. The processing rate for one normal line is 553 cans per minute. For the BAT options, the water discharged is 57.4 liters per thousand cans through water conservation techniques (see Options 1 through 3 below). Further, water conservation technology available to new sources reduces the water discharged to 14.0 liters per thousand cans. These values were derived from data collected by the Agency from can manufacturing plants of several sizes and locations. The derivation of a "normal" canmaking process line is discussed in Section IX. Also derived from these data were representative pollutant concentrations. These values summarized in Table VIII-1 (page 242).

To calculate costs for 1, 2, 4, 5, and 6 processing lines, the six-tenths power rule was applied. This rule states that the costs for plants of different sizes can be computed by multiplying the base cost by the ratio raised to the six tenths power of one plant's capacity over the base plant capacity:

$$\text{Cost for plant B} = \text{cost for plant A} \times \frac{\text{Capacity Plant B}}{\text{Capacity Plant A}}^{0.6}$$

The slight error associated with this engineering rule does not preclude its use as a mechanism for establishing costs for this industry.

The four options considered for BPT, BAT and PSES were costed as follows:

Option 0. This option includes equalization, chemical emulsion breaking, dissolved air flotation, lime precipitation and sedimentation, and vacuum filtration at the full BPT flow.

Option 1. This option includes all of Option 0 with flow reduction in the canwasher discharge achieved through countercurrent rinsing.

Option 2. This option includes Option 1 plus multimedia filtration as a polishing step after lime precipitation and clarification.

Option 3. This option includes Option 2 plus ultrafiltration after multimedia filtration.

The total costs for each option for each of tne six model size plants are displayed on Table VIII-2 (page 243). These costs represent the capital investment and operating costs.

New Sources

The new source options include Options 0 through 3 and two additional options. These are:

Option 4. This option is Option 1 with a flow reduced to 14 liters per thousand cans based on additional flow reduction achieved through design of water conservation techniques not feasible for existing plants (including either an extended stage canwasher operation or other water reuse technologies that will achieve this flow reduction).

Option 5. This option is Option 4 with multimedia polishing filtration. The same flow as in Option 4 is used.

The countercurrent rinsing design basis for new sources differs from the technology as applied in existing sources. An extended stage canwasher operation was used as the basis since this represents for many plants a suitable tradeoff between achievable water conservation and the cost of additional equipment. Costs were developed for this technology by adding additional equipment similar to the two-stage operation costed for existing sources. Additional piping, tankage, nozzles, and pumps were included to expand the six-stage operation to a nine-stage operation.

The cost estimation procedure for new sources is otherwise identical to that used for existing sources. The total costs are also presented on Table VIII-2. These costs represent the capital investment and operating costs for new source performance standards and pretreatment standards for new sources.

Treatment In Place

The costs listed in Table VIII-2 are greenfield costs that do not account for equipment that plants may already have in place. When costs are computed for an actual plant that has some of the equipment already installed, that cost component must be subtracted from the total module cost before adding subsidiary costs (costs such as engineering or contingency added at the system level as a percentage of the installed equipment cost). The compliance costs that account for treatment in place are shown in Table X-5 (page 277).

ENERGY AND NON-WATER QUALITY ASPECTS

Energy and non-water quality aspects of all of the wastewater treatment technologies described in Section VII are summarized in Tables VIII-3 and VIII-4 (pages 244 and 245). These general energy requirements are listed, the impact on environmental air and noise pollution is noted, and solid waste generation characteristics are summarized. The treatment processes are divided into two groups, wastewater treatment processes on Table VIII-3, and sludge and solids handling processes on Table VIII-4.

Energy Aspects

Energy aspects of the wastewater treatment processes are important because of the impact of energy on natural resources and the economy. Based on dcp information from 5 plants operating 13 lines, the EPA determined an energy consumption of 17.56 x 10^6 kwhr per line for canmaking operations, and 0.074 x 10^6 kwhr per line for treatment system operation. On this basis, the 224 lines operated by the canmaking industry consumed approximately 3.9 x 10^9 kwhr in 1981. Because the energy

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The energy requirements for the wastewater treatment options for the subcategory are generally low. When compared to the total plant energy usage, the wastewater treatment processes contribute less than 0.5 percent to the overall energy usage. None of the treatment options considered result in high energy consumption.

Non-Water Quality Aspects

It is important to consider the impact of each treatment process on water scarcity; air, noise, and radiation; and solid waste pollution of the environment to preclude the development of an adverse environmental impact.

Consumptive Water Loss

Where evaporative cooling mechanisms are used, water loss may result and contribute to water scarcity problems, a concern primarily in arid and seim-arid regions. These treatment options do not require substantial evaporative cooling and recycling which would cause a significant consumptive water loss.

Air Pollution

In general, none of the wastewater handling and treatment processes considered for this subcategory cause air pollution problems. For the precipitation of hexavalent chromium using SO_2 as a reducing agent, the potential exists for the evolution of SO_2 as a gas. However, proper design of the treatment tanks and proper pH control eliminates this problem. Incineration of waste oil lubricants could cause air pollution problems which need to be controlled by suitable scrubbers or precipitators, as well as proper incinerator operation and maintenance. The wastewater treatment sludges are not generally amenable to incineration because of their high noncombustible solids content.

Noise and Radiation

None of the wastewater treatment processes cause objectionable noise levels and none of the treatment processes has any potential for radioactive radiation hazards.

Solid Waste

Costs for treatment sludge handling were included in the costing analysis performed for the subcategory. To estimate the amount of treatment sludge produced as a result of the proposed treatment technologies, the mass of sludge produced annually per normal line is used. A computer program is used to estimate sludge generated by a normal line based on the removals at each treatment level given in Table X-1. A 20 percent solids content of the sludge can and a 10 percent excess of lime are the essential calculation parameters. Total annual sludge generation for each level is calculated from the number of lines operated by direct dischargers, and indirect dischargers. For new sources a plant with six normal lines is used.

The lime precipitation and settling technology produces a sludge with a high solids content, consisting of calcium salts and a high pH. When this waste stream is subjected to the RCRA hazardous waste criteria, it is judged to be nonhazardous and therefore no hazardous waste disposal costs are attributed to disposal of the sludge.

Spent lubricating oil waste is also generated by canmaking plants and is generally disposed of in a landfill or reclaimed by contract waste haulers. Based upon dcp data, the quantity of this spent lubricant is estimated to be 212.7 kkg/yr/line (12,083 gallons per year) for an average line based on data from 125 canmaking lines. Since the spent lubricant is considered to be nonhazardous under RCRA criteria, there are no RCRA related costs attributed to the disposal of this material.

Table VIII-1

WASTEWATER CHARACTERISTICS FROM CAN MAKING USED FOR COST ESTIMATES

Parameter	Value	
Chromium	4.99	mg/l
Zinc	3.7	mg/l
Aluminum	370	mg/l
Fluoride	21.2	mg/l
Iron	5.4	mg/l
Manganese	2.0	mg/l
Phosphorus	23.5	mg/l
Oil and Grease	4,721	mg/l
TSS	345	mg/l
pH	6	pH units

Table VIII-2

SUMMARY OF CAPITAL AND ANNUAL COSTS FOR MODEL PLANTS IN THE CAN MAKING SUBCATEGORY

Number of Processing Lines	Existing Source Options								New Source Options			
	0		1		2		3		4		5	
	Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual
1	443,600	201,200	364,000	176,900	385,900	181,000	578,300	329,500	331,100	188,000	348,500	196,300
2	672,300	305,000	551,700	268,100	584,900	274,400	876,600	499,400	499,900	283,800	528,200	297,500
3	857,500	389,000	703,600	342,000	746,000	350,000	1,118,000	637,000	640,000	363,400	673,700	379,450
4	1,019,100	462,300	836,200	406,400	886,500	415,900	1,328,600	757,000	760,600	431,800	800,600	450,900
5	1,165,100	528,500	956,000	464,700	1,013,600	475,500	1,519,000	865,500	869,500	493,600	915,300	515,500
6	1,299,700	589,600	1,066,500	518,400	1,130,700	530,500	1,694,600	965,500	970,100	550,700	1,021,100	575,100

Dollar base: first quarter 1982.
Capital costs in dollars.
Annual costs in dollars per year.

TABLE VIII-3

NONWATER QUALITY ASPECTS OF WASTEWATER TREATMENT

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / 1000 liters	Fuel	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Chemical Reduction	1.0	—	Mixing	None	None	None	—
Skimming	0.01-.3	—	Skimmer Drive	None	None	Concentrated	5-50 (oil)
Clarification	0.1-3.2	—	Sludge Collector Drive	None	None	Concentrated	1-10
Flotation	1.0	—	Recirculation Pump, Compressor, Skim	None	None	Concentrated	3-5
Chemical Oxidation by Chlorine	0.3	—	Mixing	None	None	None	—
Oxidation by Ozone	0.5-5.0	—	Mixing Ozone Generation	None	None	None	—
Chemical Precipitation	1.02	—	Flocculation Paddles, Mixers	None	None	Concentrated	1-10
Sedimentation	0.1-3.2	—	Sludge Collector Drive	None, Possible H_2S Evolution	None	Concentrated	1-3
Deep Bed	0.10	—	Head, Backwash Pumps	None	None	Concentrated	Variable
Ion Exchange	0.5	—	Pumps	None	Not Objectionable	None	N/A
Adsorption	0.1	—	Pumps, Evaporate During Regeneration	None	None	None/Waste Carbon	40
Evaporation	—	2.5*	Evaporate Water	None	None	Concentrated/ Dewatered	50-100
Reverse Osmosis	3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Ultrafiltration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Membrane Filtration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Electrochemical Chromium Reduction	0.2-0.8	—	Rectifier, Pump	None	None	Concentrated	1-3
Electrochemical Chromium Regeneration	2.0	—	Regeneration, Pump	None	None	None	—

* 10^6 BTU/1,000 liters

TABLE VIII-4

NONWATER QUALITY ASPECTS OF SLUDGE AND SOLIDS HANDLING

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / ton dry solids	Fuel kwh / ton dry solids	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Sludge Thickening	29-930	—	Skimmer, Sludge Rake Drive	None	None	Concentrated	4-27
Pressure Filtration	21	—	High Pressure Pumps	None	None	Dewatered	25-50
Sand Bed Drying	—	35	Removal Equipment	None	None	Dewatered	15-40
Vacuum Filter	16.7-66.8	—	Vacuum Pump, Rotation	None	Not Objectionable	Dewatered	20-40
Centrifugation	0.2-98.5	—	Rotation	None	Not Objectionable	Dewatered	15-50
Landfill	—	20-980	Haul, Landfill 1-10 Mile Trip	None	None	Dewatered	N/A
Lagooning	—	36	Removal Equipment	None	None	Dewatered	3-5

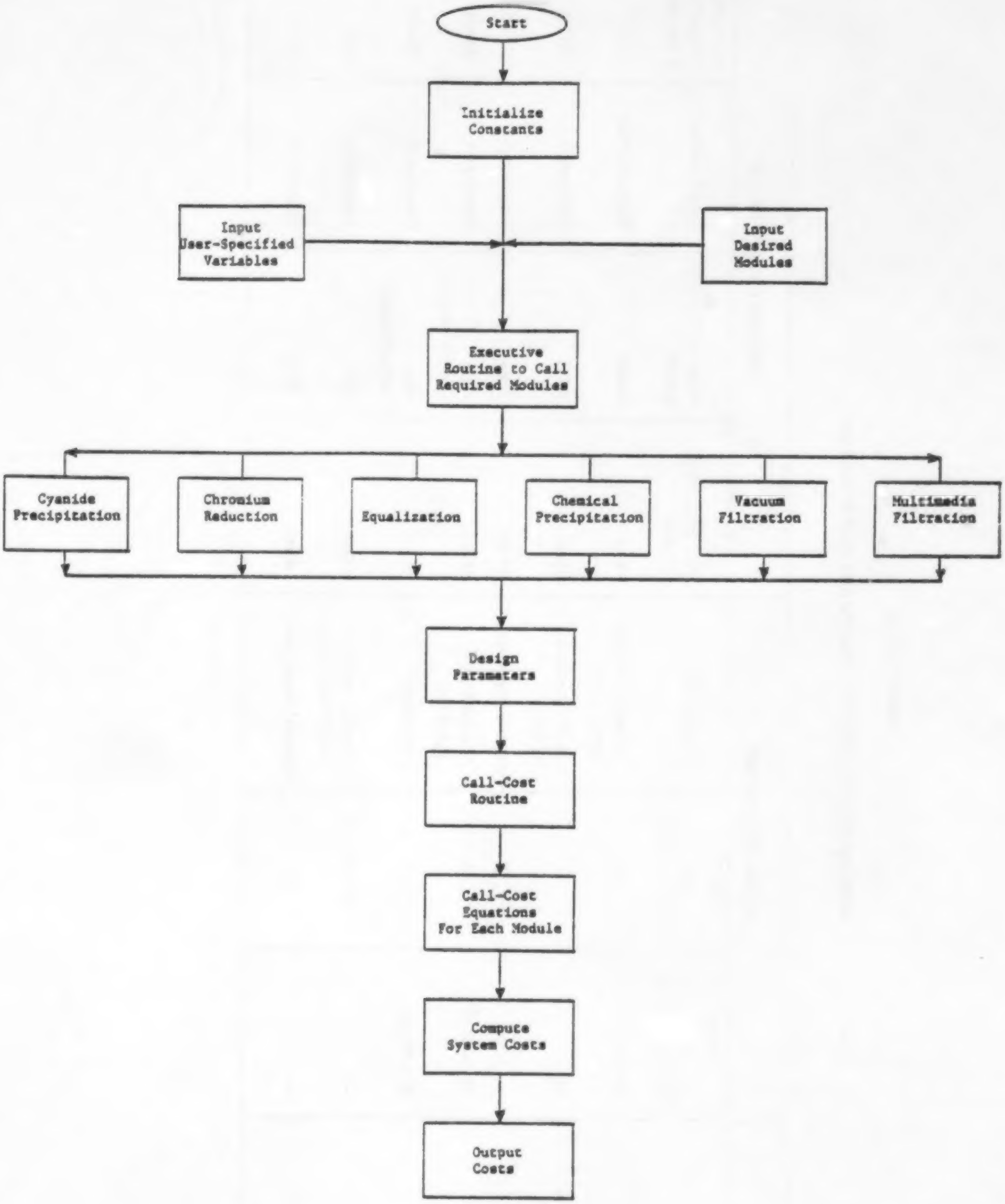

Start
Initialize Constants
Input User-Specified Variables
Input Desired Modules
Executive Routine to Call Required Modules
Cyanide Precipitation
Chromium Reduction
Equalization
Chemical Precipitation
Vacuum Filtration
Multimedia Filtration
Design Parameters
Call-Cost Routine
Call-Cost Equations For Each Module
Compute System Costs
Output Costs

Figure VIII-1

GENERAL LOGIC DIAGRAM OF DESIGN AND COST PROGRAMS

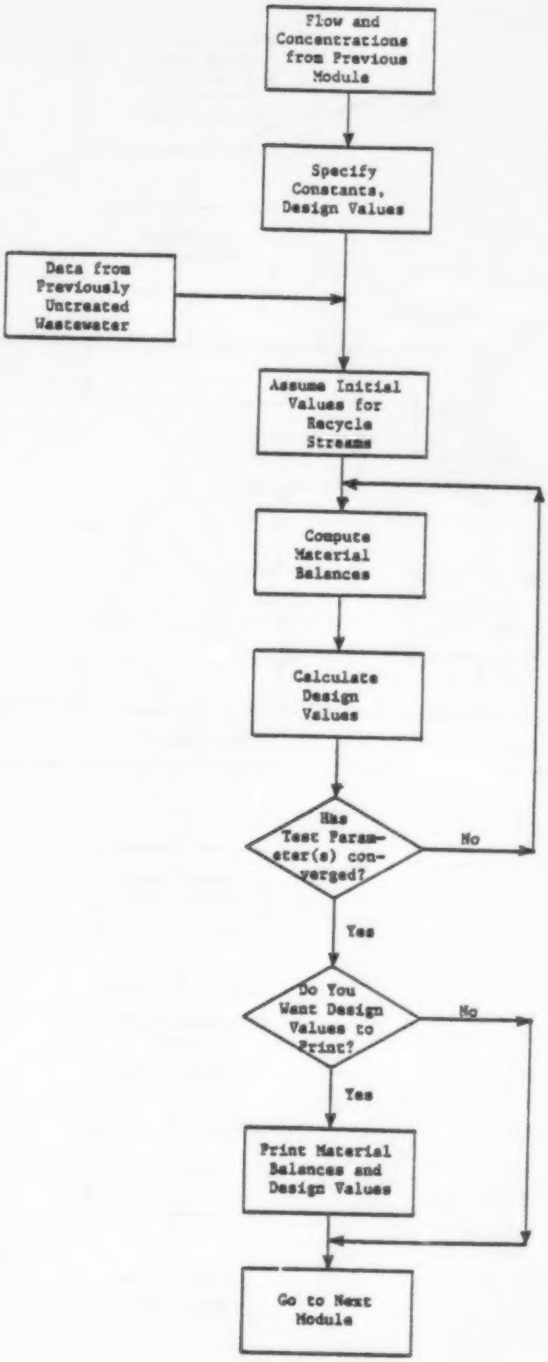

Flow and Concentrations from Previous Module
Specify Constants, Design Values
Data from Previously Untreated Wastewater
Assume Initial Values for Recycle Streams
Compute Material Balances
Calculate Design Values
Has Test Parameter(s) converged?
No
Yes
Do You Want Design Values to Print?
No
Yes
Print Material Balances and Design Values
Go to Next Module

Figure VIII-2

LOGIC DIAGRAM OF MODULE DESIGN PROCEDURE

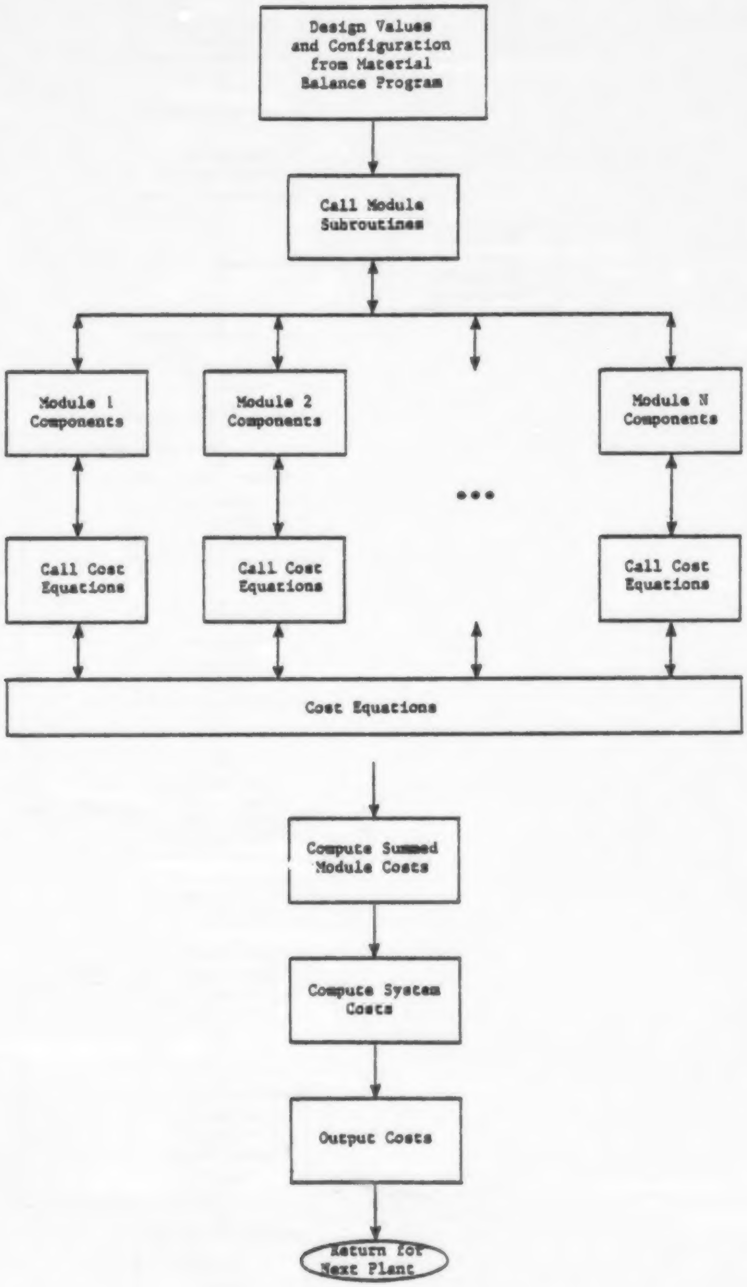

Design Values and Configuration from Material Balance Program
Call Module Subroutines
Module 1 Components
Module 2 Components
Module N Components
• • •
Call Cost Equations
Call Cost Equations
Call Cost Equations
Cost Equations
Compute Summed Module Costs
Compute System Costs
Output Costs
Return for Next Plant

Figure VIII-3

LOGIC DIAGRAM OF THE COSTING ROUTINE

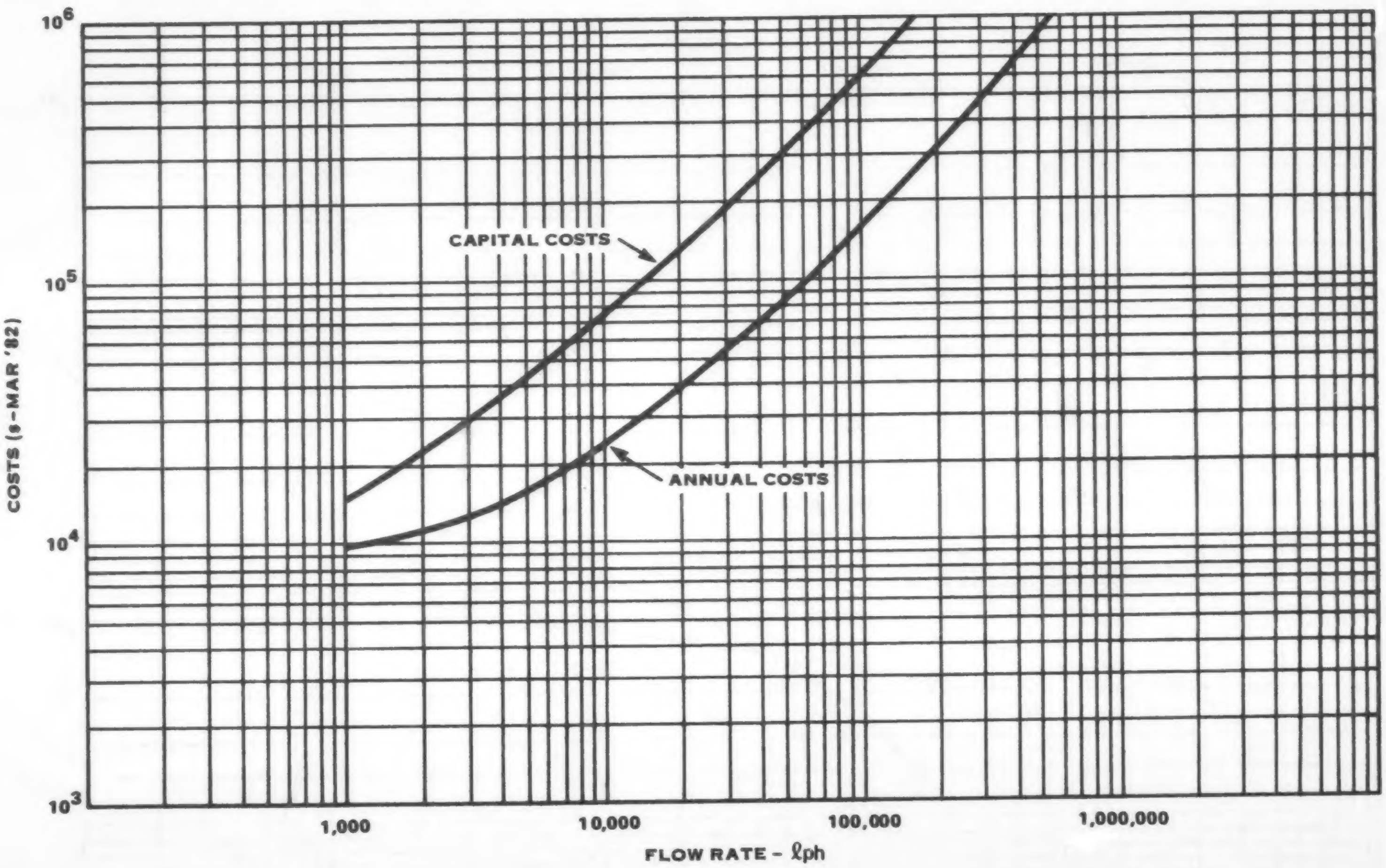


FIGURE VIII-4. COSTS FOR EQUALIZATION

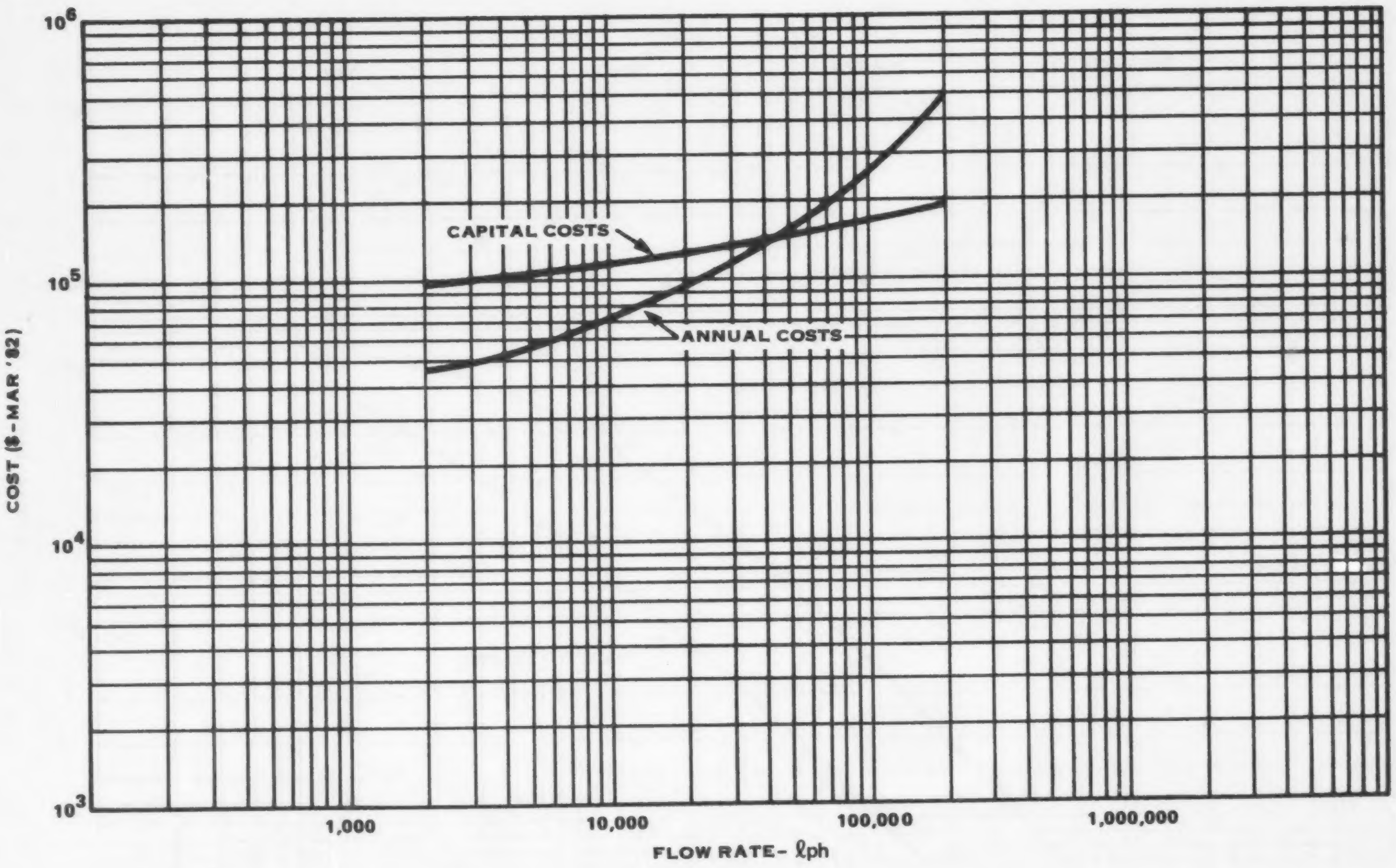


FIGURE VIII-5. COSTS FOR CHEMICAL EMULSION BREAKING

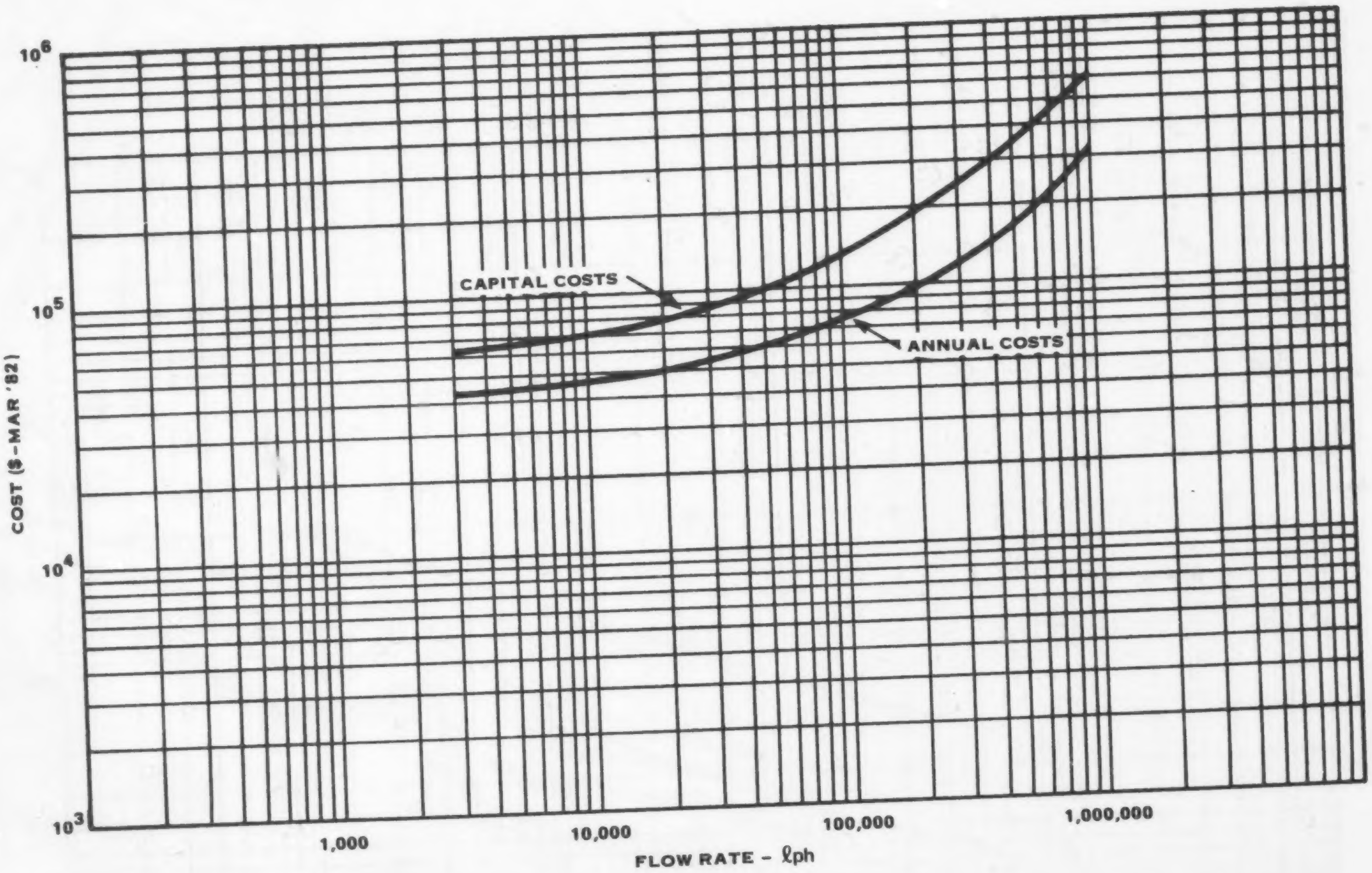


FIGURE VIII-6. COSTS FOR DISSOLVED AIR FLOTATION

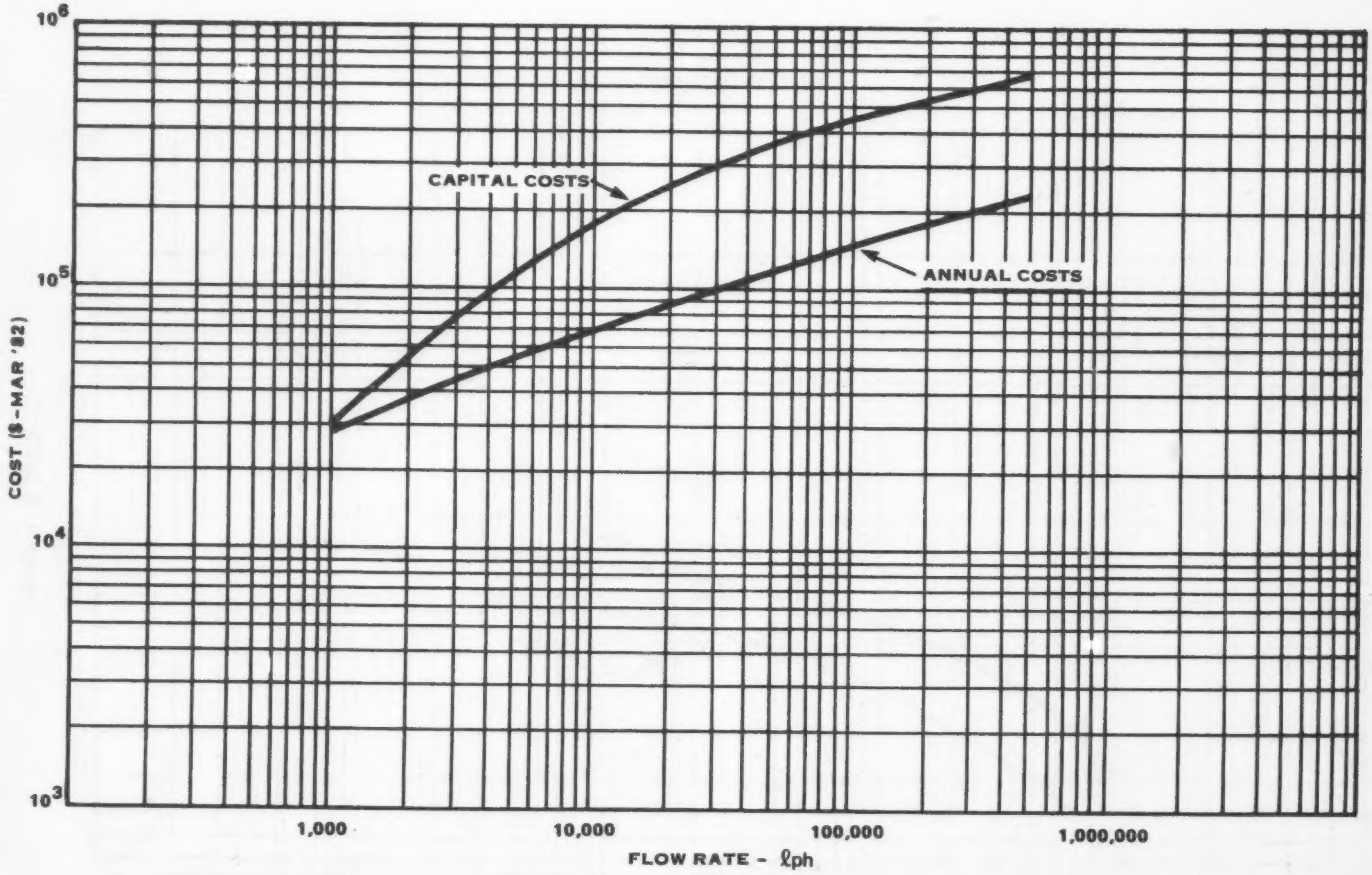


FIGURE VIII-7. COSTS FOR CHEMICAL PRECIPITATION - SEDIMENTATION

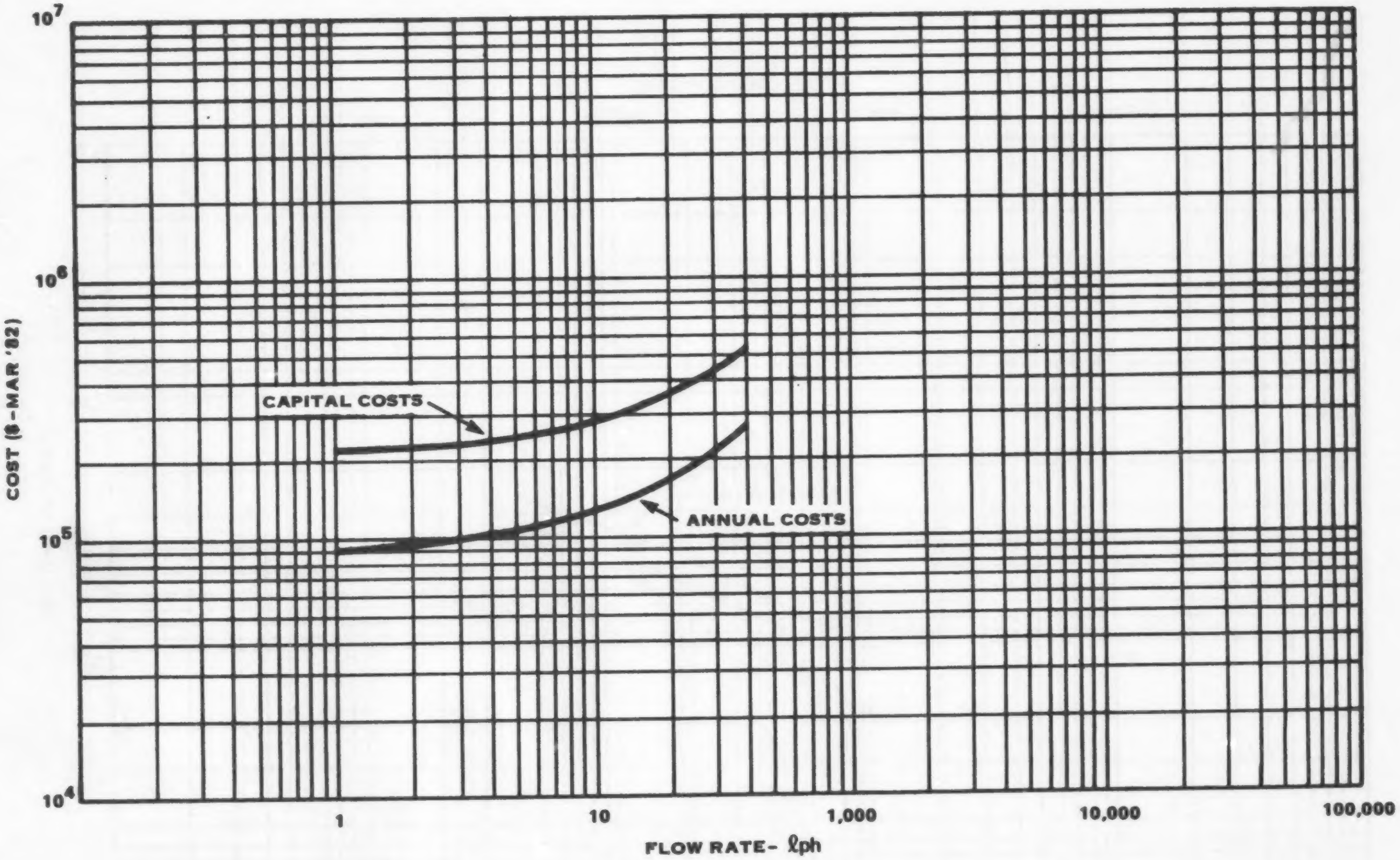


FIGURE VIII-8. COSTS FOR VACUUM FILTRATION

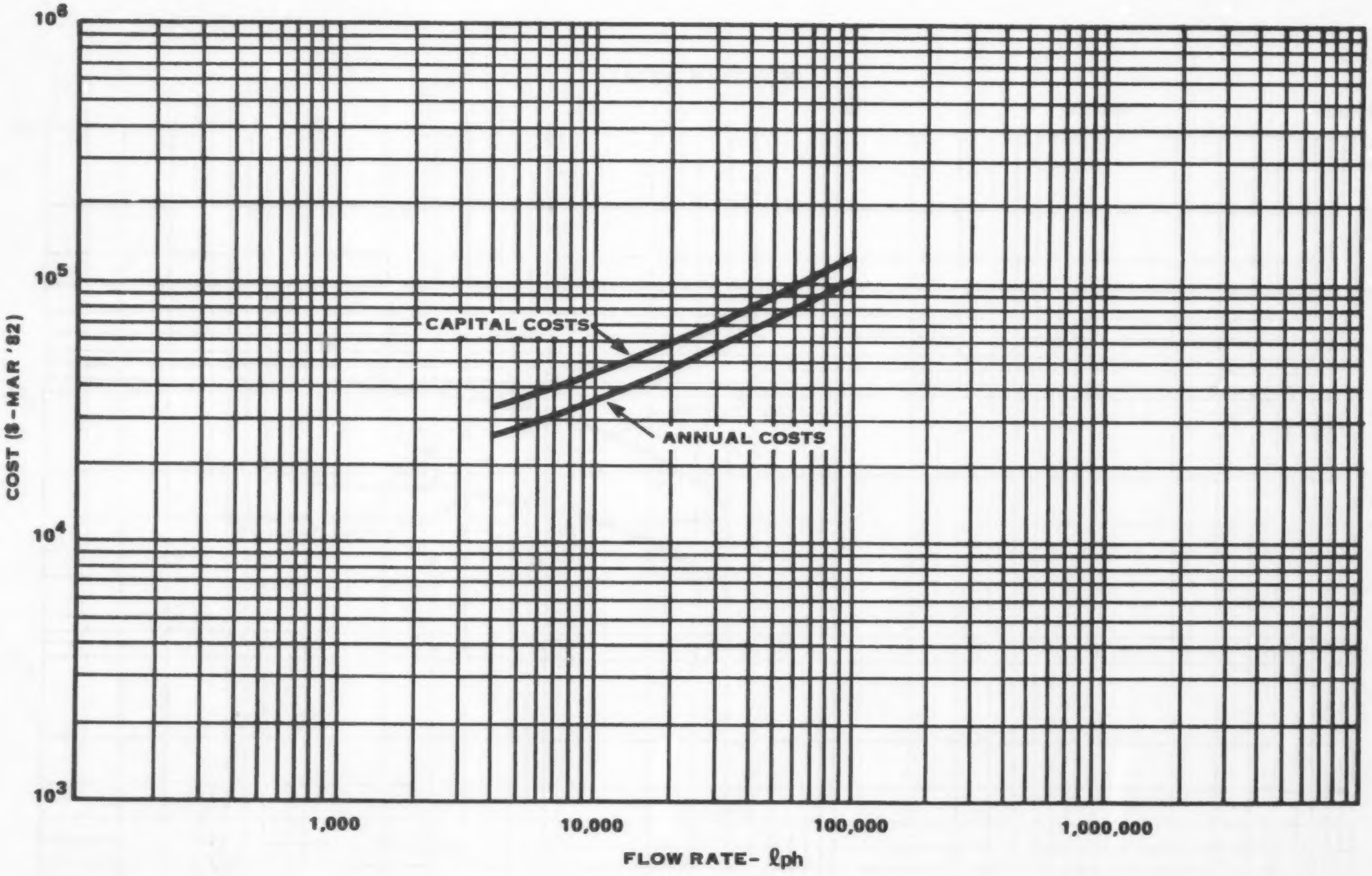


FIGURE VIII-9. COSTS FOR MULTIMEDIA FILTRATION

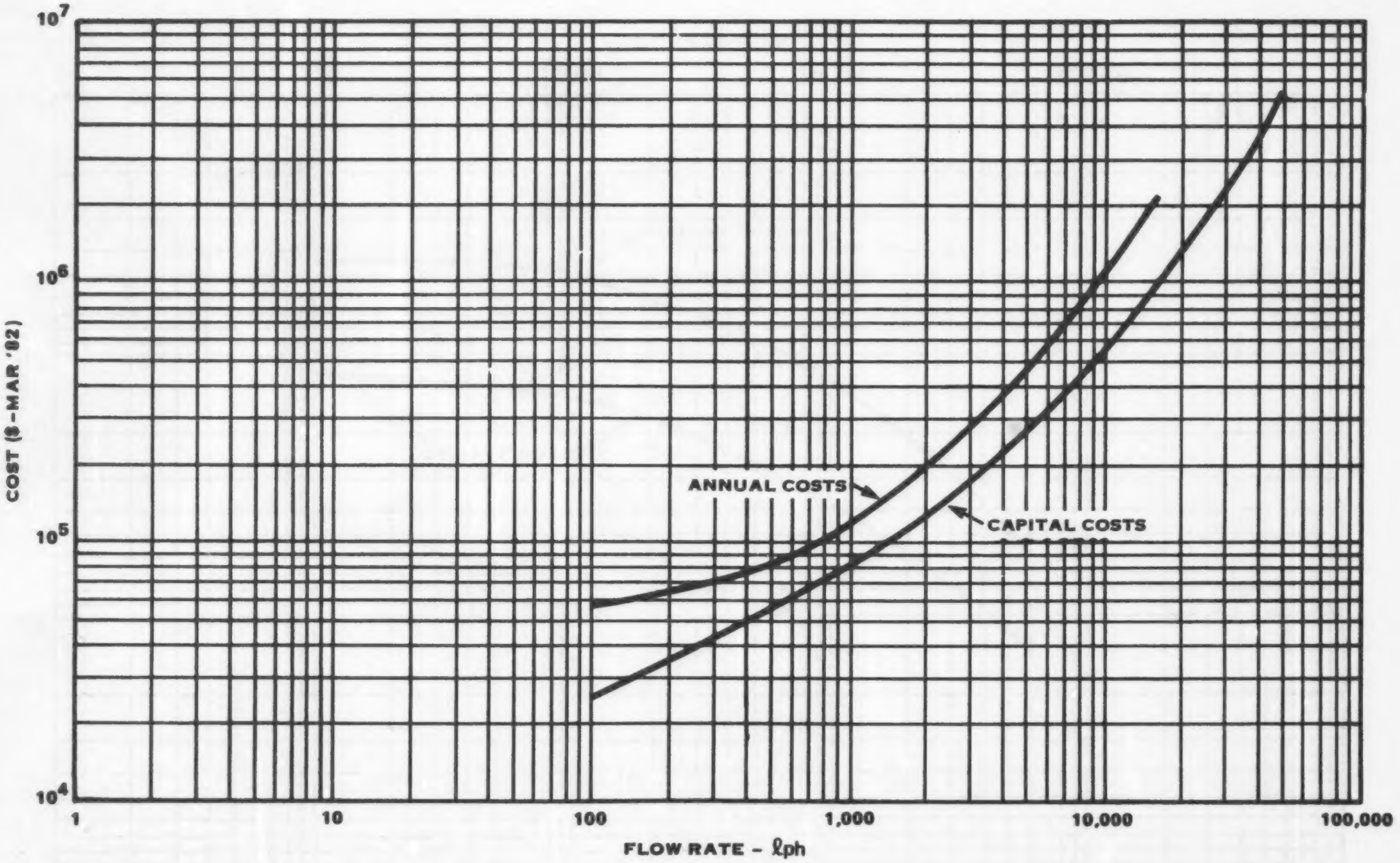


FIGURE VIII-10. COSTS FOR ULTRAFILTRATION

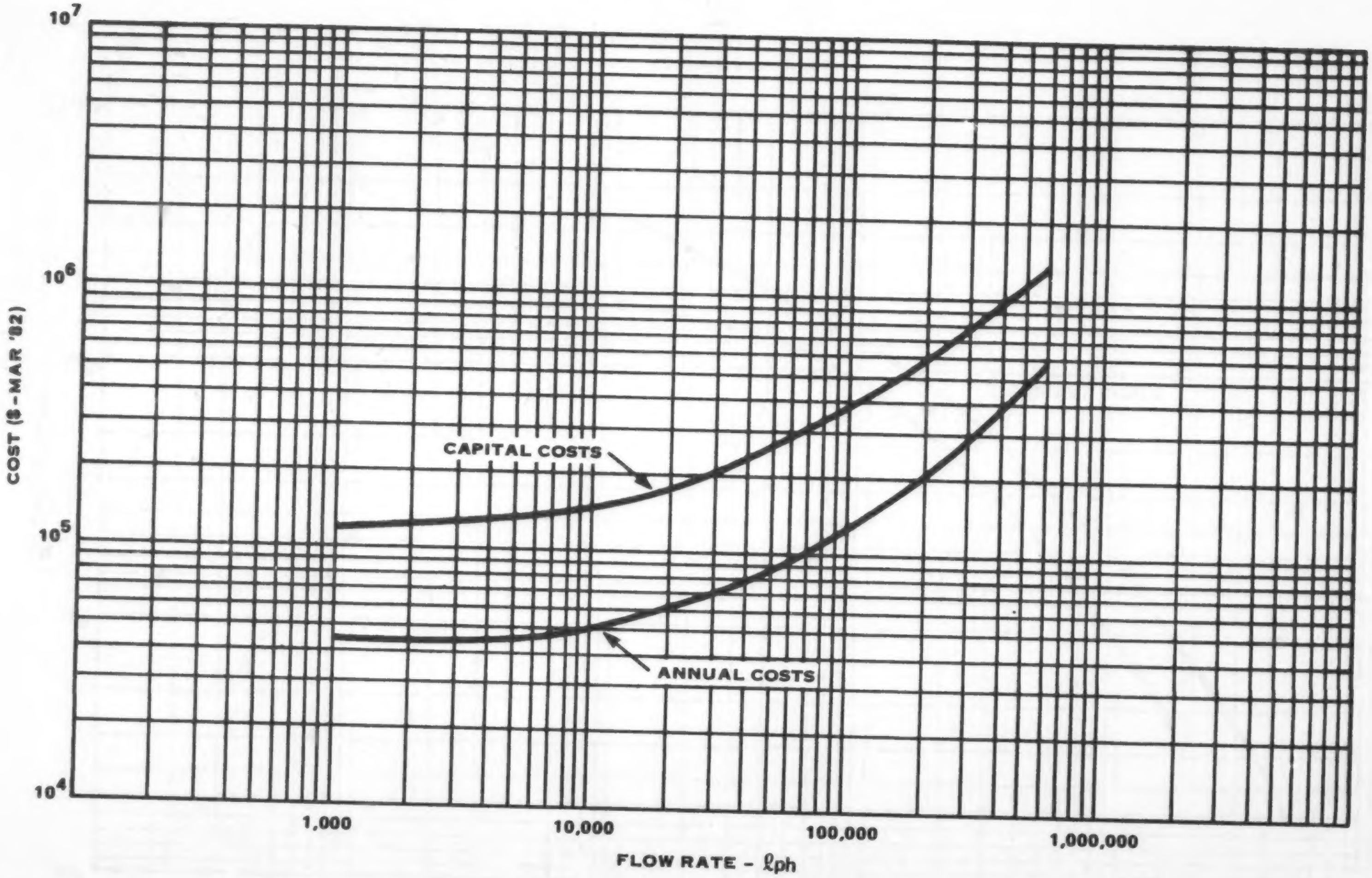


FIGURE VIII-11. COSTS FOR CYANIDE PRECIPITATION

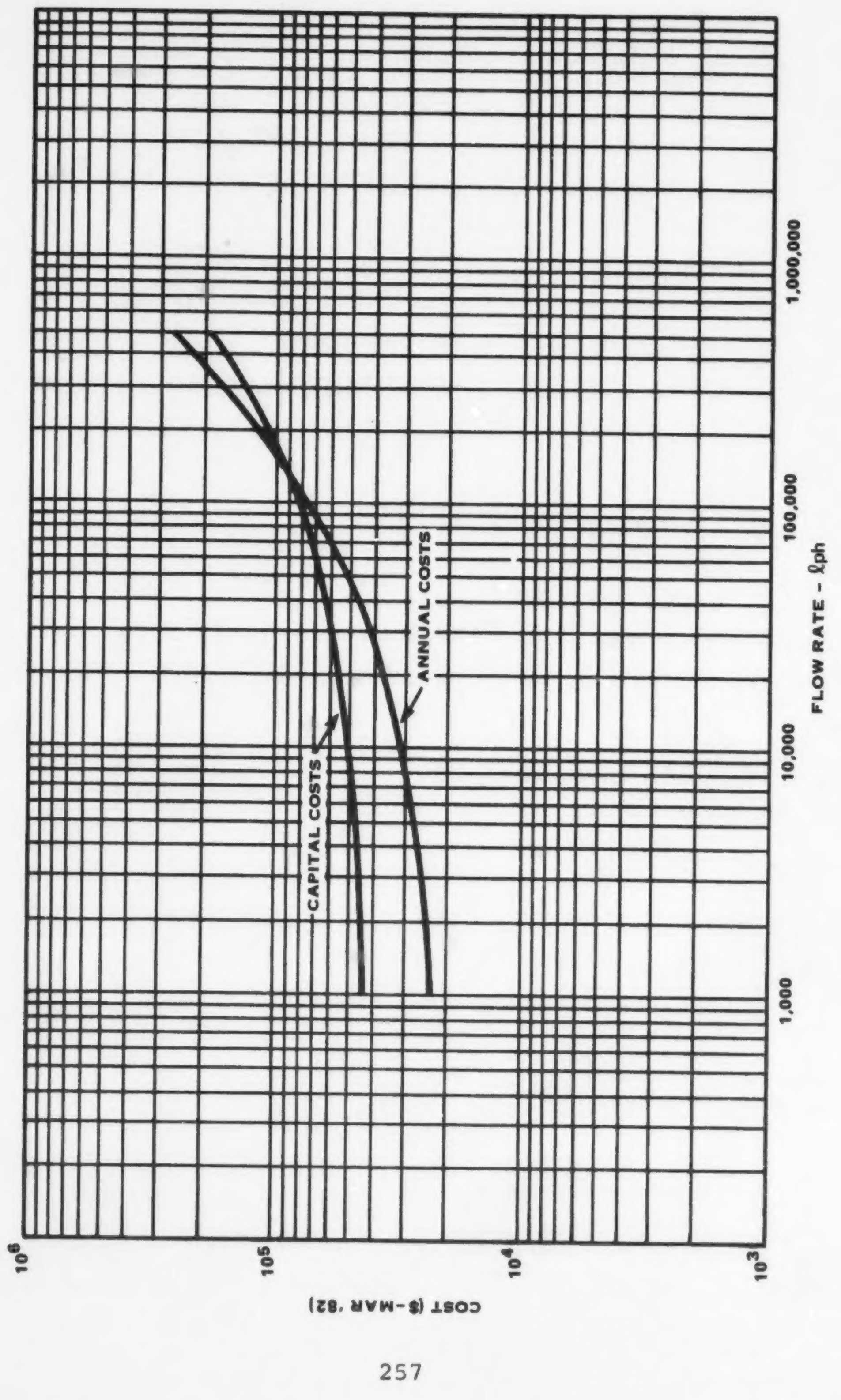


FIGURE VIII-12. COSTS FOR CHROMIUM REDUCTION

SECTION IX
BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

This section defines the effluent characteristics attainable through the application of best practicable control technology currently available (BPT). BPT reflects the performance by plants of various sizes, ages, and manufacturing processes within the canmaking subcategory.

The factors considered in defining BPT include the total cost of applying the technology in relation to the effluent reduction benefits from such application, the age of equipment and facilities involved, the process employed, non-water quality environmental impacts (including energy requirements) and other factors the Administrator considers appropriate. In general, the BPT level represents the average of the best existing performances of plants of various ages, sizes, processes or other common characteristics. Where existing performance is uniformly inadequate, BPT may be transferred from a different subcategory or category. Limitations based on transfer technology must be supported by a conclusion that the technology is, indeed, transferrable and a reasonable prediction that it will be capable of achieving the prescribed effluent limits. See Tanners' Council of America v. Train. BPT focuses on end-of-pipe treatment rather than process changes or internal controls, except where such are common industry practice.

TECHNICAL APPROACH TO BPT

EPA first studied canmaking operations to identify the processes used and the wastewaters generated during the canmaking process. Information was collected through previous work, dcp forms and specific plant sampling and analysis. The Agency used these data to determine what constituted an appropriate BPT.

Canmaking consists of cupping, drawing and ironing, and washing, where the cans are cleaned and prepared for the decoration process. These process steps generate different wastewater streams. In all wastestreams, as discussed in Sections III and IV, the volume of wastewater is related to the number of cans processed.

As a mechanism for evaluating costs and environmental benefits the Agency used the concept of a "normal" canmaking line. A normal line is defined as a production module having the average production rate per line of the industry (553 cans/min); generating wastewater at the mean wastewater level of the category (255 l/1000 cans) or at the regulatory flow used for specific options; and having raw wastewater characteristics equal to the average pollutant concentrations of the sampled aluminum plants (See Table V-8). Data on the number of lines in each plant and production rates were supplied in the dcp for each plant.

This document has already discussed some of the factors which must be considered in establishing effluent limitations based on BPT. The age of equipment and facilities and the processes employed were taken into account and are discussed fully in Section IV. Nonwater quality impacts and energy requirements are considered in Section VIII.

The general approach to BPT for this subcategory is to treat all canmaking wastewaters in a single (combined) treatment system. Normal practice is to combine wastewater for treatment because it is less expensive. Oil which is used as a lubricant and coolant during the formation of the seamless can body, and is removed during washing, must be removed from the wastewater; and hexavalent chromium, where present, must be reduced to the trivalent state so that it can be precipitated and removed along with other metals. The dissolved metals must be precipitated and suspended solids, including the metal precipitate, removed. Therefore, the strategy for BPT is reuse of rinsewaters in the canwasher; oil removal by dissolved air flotation and emulsion breaking; chromium reduction and cyanide precipitation when necessary; and follow or combine with lime and settle technology to remove metals and solids from the wastewaters. (See Figure IX-1, page 265). Regulatory flow used as the basis for calculating BPT is the average of the plants having the best water use characteristics.

SELECTION OF POLLUTANT PARAMETERS FOR REGULATION

The pollutant parameters selected for regulation in the canmaking subcategory were selected because of their frequent presence at treatable concentrations in wastewaters from the industry. In addition to oil and grease, TSS, and pH, the traditional pollutants chromium, zinc, aluminum, fluoride and phosphorus are regulated.

DEVELOPMENT OF CANMAKING SUBCATEGORY BPT

The BPT model treatment train for canmaking wastewater consists of in-process reuse of canwasher water, chromium reduction and cyanide precipitation when necessary; mixing and pH adjustment of the combined wastewaters with lime or acid to precipitate metals; oil skimming, dissolved air flotation, and chemical emulsion breaking as required to remove oil and grease plus some toxic organics; and settling to remove suspended solids plus precipitated metals. Forty-eight aluminum canmaking plants provided sufficient information on their dcps to calculate the mean production normalized process water use.

The flow basis for BPT is the mean for the 32 plants where water reuse in the canwasher is practiced. The production normalized water use for the canmaking subcategory at BPT is 176.7 l/1000 cans as presented in Table V-6.

Cyanide compounds may be used in some conversion coating formulations applied to aluminum cans and when used is reflected in the cyanide concentrations found in rinse waters from the canwasher. Cyanide removal by precipitation is the recommended cyanide control technology for conversion coating dumps and rinses.

Plants with production normalized flows significantly above the mean flow used in calculating the BPT limitations will need to reduce flows to meet the BPT limitations. Generally this reduction can be made by incorporating reuse of water within the canwasher - i.e., the same water is used for more than one operation within the canwasher before discharging it to treatment. Other specific water conservation practices applicable to reducing excess water use are detailed in Section VII.

Most of the canmaking plants sampled by EPA appear to have elements of the model BPT treatment system already in place and 12 of those submitting dcps indicate that they have all of the elements. Of the plants for which usable treatment system information from dcp was received: 53 have oil removal equipment including 17 that have emulsion breaking and 16 that have dissolved air flotation in place; 28 have equipment for chemical precipitation and clarification; 7 plants have hexavalent chromium reduction in place and 32 plants practice water reuse in the canwasher. However, observations by sampling teams and results of effluent analyses suggest that most treatment systems are not properly operated, or are not operated at all. The result is apparent inadequate treatment system effectiveness for the subcategory. Treatment effectiveness data, therefore was transferred from other categories. These data provide a sound statistical basis for predicting the effectiveness of properly operated lime and settle systems on canmaking wastewaters (see Section VII). Data in Tables V-9 and V-10 demonstrate the appropriateness of using the larger treatment effectiveness data base compiled from a number of categories with similar wastewater.

A statistical test of homogeneity was applied to raw wastewaters from the canmaking sampled plants and the combined metals data base. This test revealed the canmaking raw wastewaters to be homogeneous with those from the combined metals data base. Therefore, in the absence of data from properly operating BPT technology where it is installed at canmaking plants, the EPA considers transfer of treatment effectiveness from the combined metals data base to be appropriate. Some plant sampling days for this subcategory show performance equivalent to that of the combined metals data base.

Typical characteristics of total raw wastewater for the canmaking subcategory are given in Table V-8. The combination of lime and settle technology with oil removal and other pretreatment when necessary will reduce the concentration of regulated pollutants to the levels described in Table VII-21. When these concentrations are applied to the dcp mean wastewater flow described above, the mass of pollutants allowed to be discharged per 1000 cans is readily calculated. Table IX-1 (page 264) shows the limitations derived from this calculation.

To determine the reasonableness of these limitations, EPA reviewed the data for regulated pollutants from the sampled plants (Table V-12, page 60) to determine how many plants were meeting this BPT. One plant (ID #565) met the mass based limitations all three sampling days. A second plant (ID # 557) met all limitations except for oil and grease on two of the three sampling days and pH for all three sampling days. The third plant (ID #488) appears not to have operated its solids removal and oil removal systems on any of the three sampling days. Despite the fact that pH was well within limits all three days, zinc, aluminum, oil and grease, and TSS grossly exceeded the mass limitations all three days. The fourth plant (ID #515) data were not used for this comparison (even though it met BPT) because it has polishing filtration before discharge. All of the sampled plants had BPT technology installed except that oil removal was accomplished at three plants using gravity separation only; the fourth plant had emulsion breaking and dissolved air flotation equipment installed. Based on these comparisons, the proposed BPT limitations for the canmaking subcategory are reasonable.

Oil and grease limitations can be met with properly operated oil removal equipment (see Table VII-11) including skimming, and chemical emulsion breaking, and dissolved air flotation; and metals and TSS limitations can be met with pH adjustment and settling. Close pH control is essential. When pH falls below the lower limit, metals are not removed. At pH's above the upper limit, metals that become soluble as oxygenated anions return to solution. The proposed limitations (Table IX-1) (page 264) for the canmaking subcategory are reasonable.

In the establishment of BPT, the cost of applying a technology must be considered in relation to the effluent reduction benefits achieved by such application. The quantity of pollutants removed by BPT is displayed in Table X-4 (page 276) and the total cost of application of BPT is shown in Table X-5 (page 277). The capital cost of BPT as an increment above the cost of in-place treatment equipment is estimated to be $1,000,000. Annual cost of BPT for the canmaking subcategory is estimated to be $450,000. The quantity of pollutants removed above raw wastewater by the BPT system for the subcategory is estimated to be 7.31 million kg/yr including 4,415 kg/yr of toxic pollutants. EPA believes that the effluent reduction benefit outweighs the dollar cost of required BPT.

TABLE IX-1

BPT Effluent Limitations
Canmaking Subcategory

Pollutant or Pollutant Property	BPT Effluent Limitations Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	74.21	(0.163)	30.03	(0.066)
Zn	235.01	(0.517)	98.95	(0.217)
Al	803.98	(1.768)	328.66	(0.723)
F	10513.65	(23.130)	4664.88	(10.262)
P	2950.89	(6.491)	1206.86	(2.655)
O&G	3534.00	(7.774)	2120.40	(4.664)
TSS	7244.70	(15.938)	3534.00	(7.774)
pH	within the range of 7.5 to 10 at all times			

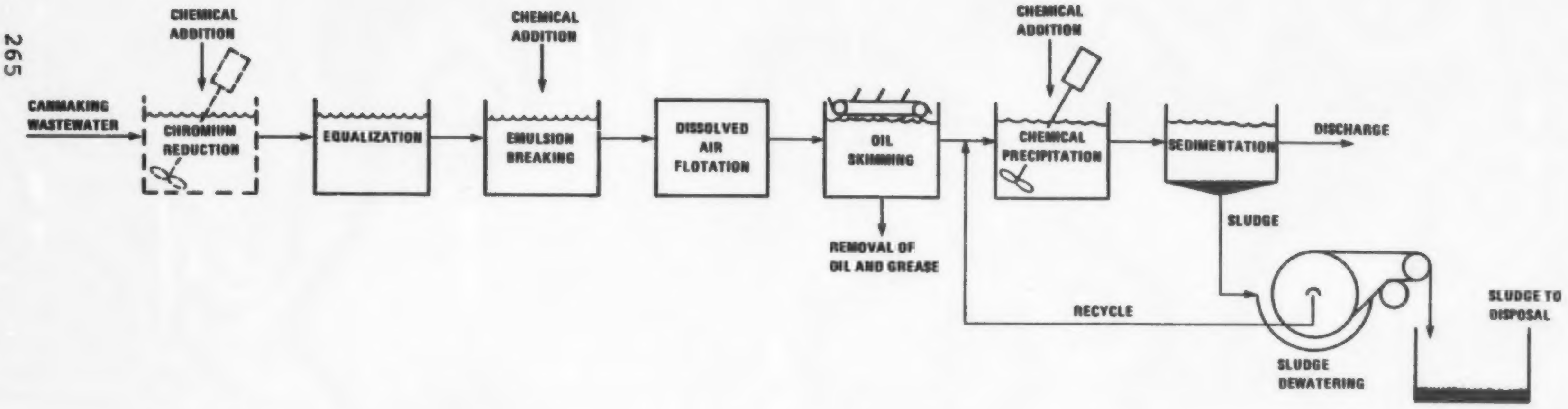

CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

FIGURE IX-1. BPT WASTEWATER TREATMENT SYSTEM

SECTION X

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The effluent limitations in this section apply to existing direct dischargers. A direct discharger is a facility which discharges or may discharge pollutants into waters of the United States. This section presents information on direct dischargers, and in addition presents total category data.

The factors considered in assessing best available technology economically achievable (BAT) include the age of equipment and facilities involved, the processes employed, process changes, non-water quality environmental impacts (including energy requirements) and the costs of application of such technology (Section 304(b)(2)(B). BAT technology represents the best existing economically achievable performance of plants of various ages, sizes, processes or other shared characteristics. As with BPT, those categories whose existing treatment system performance is uniformly inadequate may require a transfer of BAT from a different subcategory or category. BAT may include process changes or internal controls, even when these are not common industry practice.

TECHNICAL APPROACH TO BAT

In establishing BAT limitations, the Agency reviewed a wide range of technology options. These options included the range of available technologies applicable to the category .

As a general approach for the category, three levels of BAT which accomplish reduction in the discharge of toxic pollutants greater than that achieved at BPT were evaluated. Extreme technologies such as distillation and deep space disposal were rejected *a priori* as too costly or not proven.

The Agency proposes BAT based on the following treatment technologies:

- hexavalent chromium reduction, when necessary
- cyanide precipitation, when necessary
- oil skimming, chemical emulsion breaking, and dissolved air flotation
- hydroxide precipitation and sedimentation of metals
- water reuse
- two-stage countercurrent cascade spray rinse following conversion coating in the canwasher
- sludge dewatering

The Agency also considered other treatment technologies including: polishing filtration, and ultrafiltration as outlined in the following descriptions of the three BAT options considered.

Option 1

Option 1 is based on BPT end-of-pipe treatment and adds in-process controls. The technologies are:

- chromium reduction, when required
- cyanide removal, when required
- chemical emulsion breaking, dissolved air flotation, and oil skimming
- hydroxide precipitation
- settling
- in process water reduction technology
    - countercurrent cascade spray rinsing in the rinse stage of the canwasher following conversion coating
    - water reuse

Option 2

Option 2 builds on option 1 by including all of 1 technology and adding polishing filtration.

Option 3

Option 3 builds on option 2 by including all of 2 technology and adding ultrafiltration.

BAT OPTION SELECTION

The selected Option is BAT 1 (see Figure X-1, page 279). The addition of two stage countercurrent spray rinsing allows an overall reduction of 67.5 percent in water use compared to BPT. The two-stage countercurrent spray rinse is used following the conversion coating step and preceeding DI rinsing. Water use for rinsing is reduced 75 percent compared to the one-stage rinse requirements. The water use in both the rinse following acid cleaning and in the prewash is reduced the same amount, but without countercurrent rinsing. Thus the rinse water reduction is 75 percent overall. However, an allowance of 10 percent of the BPT water use (i.e. 17.7 l/1000 cans out of 176.7 l/1000 cans) is allocated for non-rinse purposes (e.g. oil sump discharge, ion exchange column regeneration, fume scrubber discharge, batch dumps of the acid cleaner and conversion coating spray recycle sumps). The overall water use for the selected BAT option is (0.10 x 176.7) plus (0.25 x 0.90 x 176.7) which equals 0.325 x 176.7 or 57.43 l/1000 cans. Section VII contains the details of assumptions and calculations used to establish the basis of achievable countercurrent rinse turn-down ratio. The theoretically achievable rinse water reduction is greater than that used for BAT. The calculations in Section VII show that 2-stage countercurrent rinsing could reduce rinse water requirements to 25.7 l/1000 cans. However, because the BAT limitations are for existing sources, and retrofitting of baffles and additional spray rinse racks is the method of achieving countercurrent rinsing in the fixed space of an existing canwasher, the 2-stage rinse is not expected to be as effective as if the full length were available as in a new installation. The actual rinse water use of 39.78 l/1000 cans for BAT is therefore more than 50 percent greater than the theoretically achievable value. The selected BAT will remove 184 kg/yr of toxic pollutants over the pollutant removal achieved by BPT. The economic impact analysis indicates that BAT is economically achievable.

The incremental pollutant removal benefits of BAT 2 (see Figure X-2, page 280) above BAT 1 would be the removal annually of 18 kg of total toxics and 10,000 kg of other pollutants (see Table X-2). Addition of filtration therefore would result in the additional removal of only about 0.01 kg per day per direct discharger. The Agency concluded that filtration for existing facilities would achieve little additional toxic pollutant reduction.

BAT option 3 (see Figure X-3, page 281) was not proposed because of the very substantial costs and extremely low additional pollutant removals. Removals were less than one kilogram of additional toxics removal above the selected BAT option, and capital and annual cost were about five times those of the selected option.

Industry Cost and Effluent Reduction Benefits of Treatment Options

An estimate of capital and annual costs for BPT, BAT 1, BAT 2, and BAT 3 was prepared. The capital cost of treatment technology in place according to dcps was also calculated using the methodology in Section VIII. Results are presented in Table X-5 (page 277).

Pollutant reduction benefits were derived by (a) characterizing raw wastewater and effluent from each proposed treatment system in terms of concentrations produced and production normalized discharges (Table X-1, page 273) for each significant pollutant found; (b) calculating the quantities removed and discharged in one year by a "normal line" (Table X-2 page 274); and (c) calculating the quantities removed and discharged in one year for the industry - direct and indirect dischargers (Table X-3, page 275). Table X-4 (page 276) summarizes treatment performances for BPT and each BAT option by giving the mass of pollutants removed and discharged for each option for direct dischargers. Tables X-1 through X-3 present pollutant reduction benefits for all plants in the category. Table X-4 presents pollutant reduction benefits for direct dischargers in the category. The pollutant reduction benefit table for indirect dischargers is presented in Section XII. Table X-5 (page 277) presents costs for plants with 1 through 6 normal lines, total for direct dischargers, and total for indirect dischargers. All pollutant parameter calculations were based on mean raw wastewater concentrations for visited plants (Table V-8, page 50) and mean water use for the treatment option.

REGULATED POLLUTANT PARAMETERS

The raw wastewater concentrations from individual operations were examined to select appropriate pollutant parameters for specific regulation. In Section VI each of the toxic pollutants was evaluated and a determination was made as to whether or not to further consider them for regulation. Pollutants were not considered for regulation if they were not detected, detected at non-quantifiable levels, unique to a small number of plants, or not treatable using technologies considered. All toxic pollutants listed for further consideration are discussed in this Section. Several toxic or non-conventional metal pollutants are regulated.

The Agency found small amounts of several toxic organic compounds (collectively referred to as total toxic organics or TTO) in canmaking wastewaters. The concentration present is 2.73 mg/l (see Table V-8, page 50). The percent removal of organics by oil skimming from coil coating, copper forming and aluminum forming plants is presented in Section VII. The average removal of organics in aluminum forming by oil skimming is about 97 percent. This removal rate is used for projecting the effectiveness of oil skimming in removing TTO in canmaking because some of the rolling oils from forming are carried into the canmaking operation and the raw wastewater levels of oil in canmaking and aluminum forming are relatively similar. Except for methylene chloride, all of the toxic organic pollutants found in canmaking are found in coil coating, aluminum forming, or copper forming and have been shown to be removed by oil removal. TTO is not regulated at BAT because it is incidentally removed with oil and grease which is adequately controlled at BCT.

Pollutant parameters selected for regulation in canmaking at BAT are: chromium, zinc, aluminum, fluoride, and phosphorus. The toxic metals selected for specific regulation are total chromium and zinc. The effluent limitations achieved by application of the selected BAT Option are also presented. Hexavalent chromium is not regulated specifically because it is included in total chromium. Only the trivalent form is removed by the lime and settle technology. Therefore the hexavalent form must be reduced to meet the limitation on total chromium. Copper, lead and nickel are not regulated because they are present at low concentrations and will be adequately removed by the suggested technology when it is operated to remove the other regulated pollutants.

Aluminum is regulated at BAT primarily because it is always present in the wastewaters and it is present in high concentrations. In these proposed regulations, only two toxic metals are regulated. If process technology is changed eliminating the introduction of those two metals, but introducing other toxic metals, the regulation of aluminum will assure their control.

Fluoride and phosphorus are regulated at BAT because they are commonly recognized pollutants found in the wastewaters from most canwashers and their control will help assure the proper operation of lime and settle technology.

CANMAKING SUBCATEGORY BAT

BAT Regulatory Flow Calculations

The BAT regulatory flow was developed by assuming that a six stage canwasher (see Figure III-3) was modified to have a countercurrent rinse after the conversion coating stage. This modification of the process is discussed in Section VII. Using the model BAT system, the flow calculation assumes that countercurrent cascade rinsing is used in the canwasher. The BAT wastewater flow was obtained using visited plant data as a model to determine what portion of total plant flow (all operations) is attributable to rinsing.

The BAT wastewater allowance for canmaking becomes 57.43 l/1000 cans which is 32.5 percent of the BPT wastewater allowance, as discussed earlier in this section. This water use will be used to calculate expected performance for BAT.

BAT Effluent Limitations Calculation

The end-of-pipe treatment applied to the BAT regulatory flow detailed above, would produce the effluent concentrations of regulated pollutants shown in Section VII, Table VII-21 for precipitation and sedimentation (lime and settle) technology.

When these concentrations are applied to the plant water use described above, the mass of pollutant allowed to be discharged per million cans produced can be calculated. Table X-6 shows the limitations derived from this calculation. The pollutants listed as "considered for regulation" in Table VI-1, for which regulation is not proposed, will be adequately removed coincidentally if the regulated pollutants are removed to the specified levels.

DEMONSTRATION STATUS

Each element of the BAT system is demonstrated however, no sampled canmaking plants use the BAT technology in its entirety. The BAT model system has the same end-of-pipe treatment as BPT and twelve plants have the model end-of-pipe treatment equipment in place. Data supplied by the canmaking companies in their dcp responses indicate that six plants achieve the BAT regulatory flow using countercurrent cascade rinsing in the canwasher. The in-process water use reduction and end-of-pipe treatment are both demonstrated.

TABLE X-1
SUMMARY OF TREATMENT EFFECTIVENESS
FOR BPT, BAT, PSES
CANMAKING SUBCATEGORY

PARAMETER	RAW WASTE		BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)		BAT 3 (PSES 3)	
	mg/1	g/10^6cans	mg/1	g/10^6cans	mg/1	g/10^6cans	mg/1	g/10^6cans	mg/1	g/10^6cans
FLOW 1/10^3cans		255.80		176.70		57.40		57.40		57.40
CHROMIUM	1.006	257.33	0.80	14.13	0.08	4.59	0.07	4.01	0.07	4.01
ZINC	0.924	236.35	0.30	53.01	0.30	17.22	0.23	13.20	0.23	13.20
ALUMINUM	138.300	35377.14	1.11	196.13	1.11	63.71	0.74	42.47	0.74	42.47
FLUORIDE	16.740	4282.09	14.50	2562.15	14.50	832.30	9.67	555.05	9.67	555.05
IRON	1.397	357.35	0.41	72.44	0.41	23.53	0.28	16.07	0.28	16.07
MANGANESE	1.851	473.48	0.21	37.10	0.21	12.05	0.14	8.03	0.14	8.03
PHOSPHORUS	6.060	1550.14	4.08	720.93	4.08	234.19	2.72	156.12	2.72	156.12
OIL & GREASE	6596.000	1,680,000.	10.00	1767.00	10.00	574.00	10.00	574.00	4.00	229.60
TSS	471.000	120481.80	12.00	2120.40	12.00	688.80	2.60	149.24	2.60	149.24
TTO	2.730	698.33	0.08	14.13	0.08	4.59	0.08	4.59	0.08	4.59

TABLE X-2
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CANMAKING SUBCATEGORY - NORMAL LINE

PARAMETER	RAW WASTE	BPT (PSES 0)		BAT 1 (PSES 1)		BAT 2 (PSES 2)		BAT 3 (PSES 3)	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
FLOW 1/10^3 cans	255.80		176.70		57.40		57.40		57.40
1/yr (10^6)	50.80		35.10		11.40		11.40		11.40
CHROMIUM	51.10	48.29	2.80	50.19	0.91	50.30	0.79	50.30	0.79
ZINC	46.93	36.40	10.53	43.51	3.42	44.31	2.62	44.31	2.62
ALUMINUM	7025.64	6986.67	38.96	7012.98	12.65	7017.20	8.43	7017.20	8.43
FLUORIDE	850.39	341.44	508.95	685.09	165.30	740.15	110.23	740.15	110.23
IRON	70.96	56.57	14.39	66.29	4.67	67.77	3.19	67.77	3.19
MANGANESE	94.03	86.65	7.37	91.63	2.39	92.43	1.59	92.43	1.59
PHOSPHORUS	307.84	164.64	143.20	261.33	46.51	276.84	31.00	276.84	31.00
OIL & GREASE	335076.80	334725.80	351.00	334962.80	114.00	334962.80	114.00	335031.20	45.60
TSS	23926.80	23505.60	421.20	23790.00	136.80	23897.16	29.64	23897.16	29.64
TTO	138.68	135.87	2.80	137.77	130.91	137.77	0.91	137.77	0.91
TOTAL TOXICS	236.72	220.58	16.14	231.48	5.24	232.39	4.33	232.39	4.33
TOTAL OTHER	367352.47	365867.39	1485.08	366870.14	482.33	367054.36	298.11	367122.76	229.71
CONVENTIONALS	359003.60	358231.40	772.20	358752.80	250.80	358859.96	143.64	358928.36	75.24

TABLE X-3
TOTAL TREATMENT PERFORMANCE
CANMAKING SUBCATEGORY

PARAMETER	RAW WASTE	BPT & PSES 0		BAT 1 & PSES 1		BAT 2 & PSES 2		BAT 3 & PSES 3	
		Removed	Discharged	Removed	Discharged	Removed	Discharged	Removed	Discharged
	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr
FLOW $1/10^3$ cans	255.80		176.70		57.40		57.40		57.40
$1/yr$ (10^6)	11380.		7862.		2554.		2554.		2554.
CHROMIUM	11447.47	10818.48	628.99	11243.18	204.28	11268.72	178.75	11268.72	178.75
ZINC	10514.38	8155.66	2358.72	9748.30	766.08	9927.05	587.32	9927.05	587.32
ALUMINUM	1,570,000.	1,560,000.	8727.26	1,570,000.	2834.49	1,570,000.	1889.66	1,570,000.	1889.66
FLUORIDE	190487.80	76483.00	114004.80	153460.60	37027.20	165794.49	24693.31	165794.49	24693.31
IRON	15896.74	12673.15	3223.58	14849.76	1046.97	15181.73	715.00	15181.73	715.00
MANGANESE	21062.89	19411.79	1651.10	20526.64	536.25	20705.39	357.50	20705.39	357.50
PHOSPHORUS	68957.95	36879.36	32078.59	58539.26	10418.68	62012.16	6945.79	62012.16	6945.79
OIL & GREASE	75,000,000.	74,900,000.	78624.00	75,000,000.	25536.00	75,000,000.	25536.00	75,000,000.	10214.40
TSS	5,350,000.	5,260.000.	94348.80	5,320,000.	30643.20	5,350,000.	6639.36	5,350,000.	6639.36
TTO	31065.21	30436.22	628.99	30860.92	204.28	30860.92	204.28	30860.92	204.28
TOTAL TOXICS	53027.07	49410.36	3616.70	51852.41	1174.65	52056.70	970.36	52056.70	970.36
TOTAL OTHER	82,200,000.	81,900,000.	332658.14	82,100,000.	108042.81	82,200,000.	66776.64	82,200,000.	51455.04
CONVENTIONALS	80,400,000.	80,200,000.	172972.80	80,300,000.	56179.20	80,300,000.	32175.36	80,300,000.	16853.76

TABLE X-4
TREATMENT PERFORMANCE - DIRECT DISCHARGERS
CANMAKING SUBCATEGORY

PARAMETER	RAW WASTE	BPT		BAT 1		BAT 2		BAT 3	
		Removed	Discharged	Removed	Discharged	Removed	Discharged	Removed	Discharged
	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr
FLOW 1/10^{3}cans	255.80		176.70		57.40		57.40		57.40
1/yr (10^6)	1016.		702.		228.		228.		228.
CHROMIUM	1022.09	965.93	56.16	1003.85	18.24	1006.13	15.96	1006.13	15.96
ZINC	938.78	728.18	210.60	870.38	68.40	886.34	52.44	886.34	52.44
ALUMINUM	140512.80	139733.58	779.22	140259.72	253.08	140344.08	168.72	140344.08	168.72
FLUORIDE	17007.84	6828.84	10179.00	13701.84	3306.00	14803.08	2204.76	14803.08	2204.76
IRON	1419.35	1131.53	287.82	1325.87	93.48	1355.51	63.84	1355.51	63.84
MANGANESE	1880.61	1733.19	147.42	1832.73	47.88	1848.69	31.92	1848.69	31.92
PHOSPHORUS	6156.96	3292.80	2864.16	5226.72	930.24	5536.80	620.16	5536.80	620.16
OIL & GREASE	6,700,000.	6,690,000.	7020.00	6,690,000.	2280.00	6,690,000.	2280.00	6,700,000.	912.00
TSS	478536.00	470112.00	8424.00	475800.00	2736.00	477943.20	592.80	477943.20	592.80
TTO	2773.68	2717.52	56.16	2755.44	18.24	2755.44	18.24	2755.44	18.24
TOTAL TOXICS	4734.56	4414.64	322.92	4629.68	104.88	4647.92	86.64	4647.92	86.64
TOTAL OTHER	7,340,000.	7,310,000.	29701.62	7,330,000.	9646.68	7,340,000.	5962.20	7,340,000.	4594.20
CONVENTIONALS	7,180,000.	7,160,000.	15444.00	7,170,000.	5016.00	7,170,000.	2872.80	7,170,000.	1504.80

TABLE X-5

TREATMENT COSTS

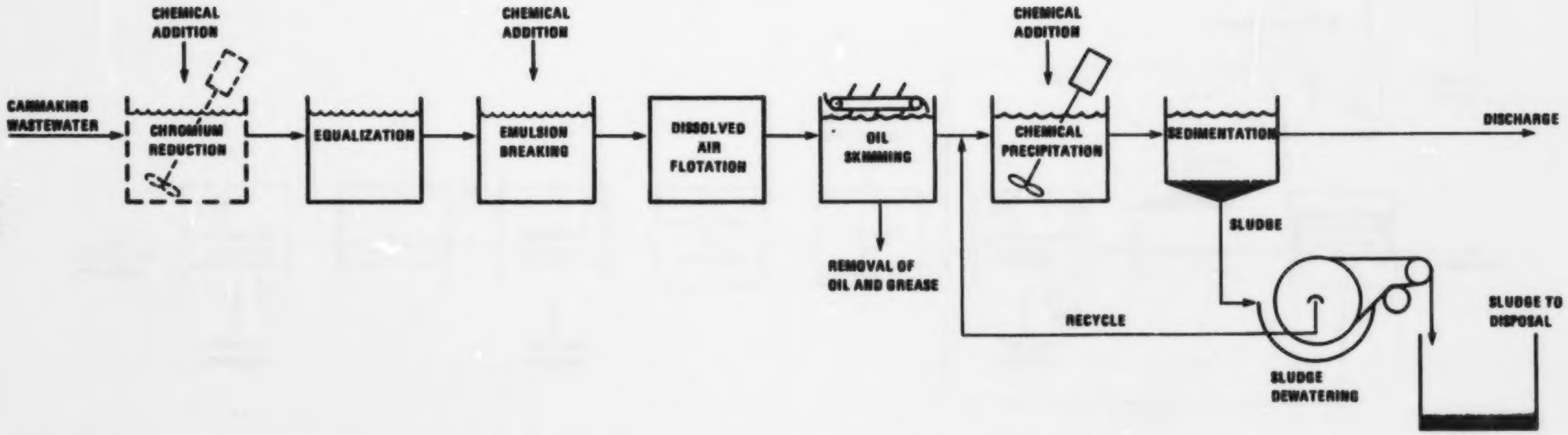
	BPT or PSES 0		BAT 1 or PSES 1		BAT 2 or PSES 2		BAT 3 or PSES 3	
	Capital	Annual	Capital	Annual	Capital	Annual	Capital	Annual
Direct Dischargers	1.0	0.45	0.68	0.42	0.91	0.45	3.31	2.30
Indirect Dishcargers	34.0	18.40	27.60	16.70	31.80	17.40	43.50	32.90
Subcategory Total	35.0	18.85	28.28	17.12	32.71	17.85	46.81	35.20

NOTE: Costs are presented in 1982 dollars (rounded to millions) and are above treatment equipment in place.

TABLE X-6

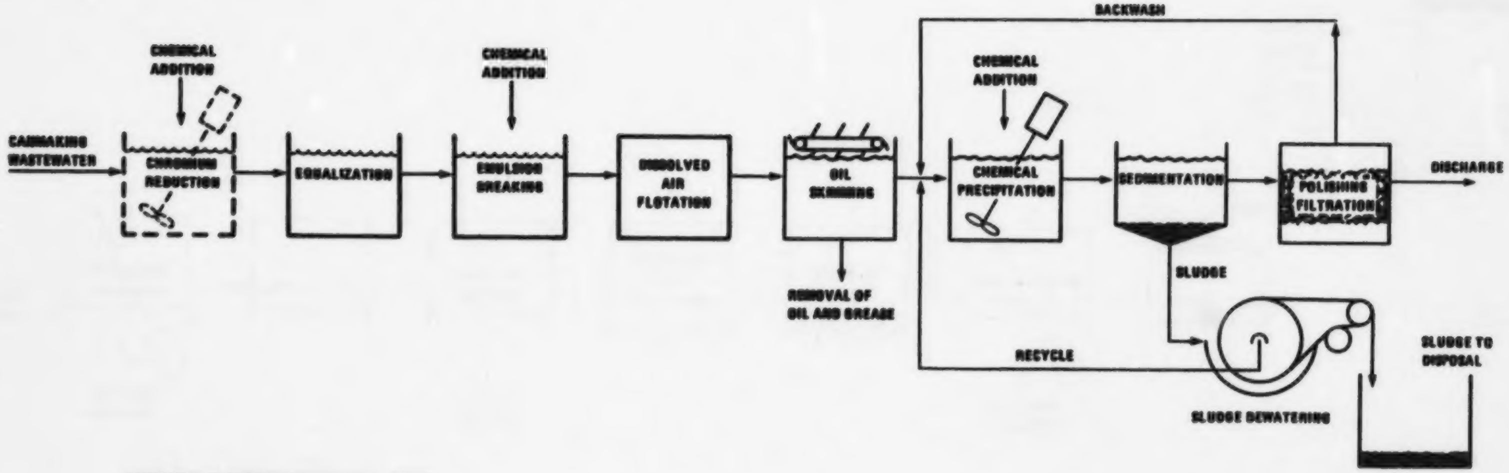
BAT EFFLUENT LIMITATIONS
CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	BAT Effluent Limitations			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	24.10	(0.053)	9.75	(0.021)
Zn	76.34	(0.167)	32.14	(0.070)
Al	261.17	(0.574)	106.76	(0.234)
F	3415.30	(7.513)	1515.36	(3.333)
P	958.58	(2.108)	392.04	(0.862)


CHEMICAL ADDITION
CANMAKING WASTEWATER
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

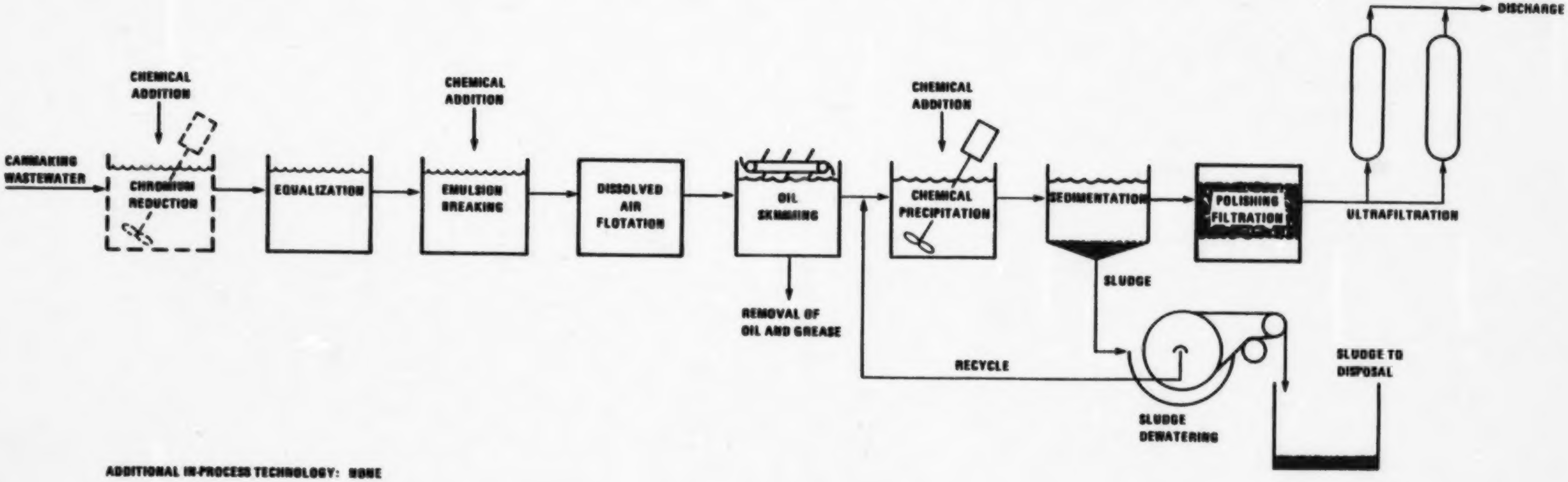
ADDITIONAL IN-PROCESS TECHNOLOGY: WATER USE REDUCTION USING 2-STAGE COUNTERCURRENT SPRAY RINSE IN CANWASHER, PLUS REUSE.

FIGURE X-1. BAT LEVEL 1 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
BACKWASH
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
POLISHING FILTRATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE X-2. BAT LEVEL 2 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
RECYCLE
SEDIMENTATION
SLUDGE
SLUDGE DEWATERING
POLISHING FILTRATION
ULTRAFILTRATION
DISCHARGE
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE X-3. BAT LEVEL 3 WASTEWATER TREATMENT SYSTEM

SECTION XI
NEW SOURCE PERFORMANCE STANDARDS

This section presents effluent characteristics attainable by new sources through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including where practicable, a standard permitting no discharge of pollutants. Five levels of technology are discussed with respect to costs, performance, and effluent reduction benefits. The rationale for selecting one of the technologies is outlined. The selection of pollutant parameters for specific regulation is discussed, and discharge limitations for the regulated pollutants are presented.

TECHNICAL APPROACH TO NSPS

As a general approach for the category, five levels of NSPS options were evaluated. The levels are generally identical to or build on BAT technology options. The BAT options and the detailed discussion and evaluation of them carried out in Section X are incorporated here by specific reference rather than repeated in this section.

NSPS options 1, 2, and 3 are identical to BAT 1, BAT 2, and BAT 3, respectively which are described in detail in Section X. The schematic diagrams of those systems are presented in Figures X-1, X-2, and X-3. In summary form, the two additional NSPS treatment options are:

At NSPS 4:

- in-process water use reduction
    - extended multi-stage canwasher or its equivalent
- end-of-pipe (identical to NSPS 1)
    - chromium reduction, when required
    - cyanide removal, when required
    - chemical emulsion breaking, dissolved air flotation, oil skimming
    - hydroxide precipitation
    - sedimentation

At NSPS 5: All of NSPS 4 plus end-of-pipe polishing filtration.

An option requiring no discharge of process wastewater pollutants was also considered. One plant is achieving this level of pollutant reduction using water use reduction, ultrafiltration, reverse osmosis, and water reuse. This system for pollutant reduction is costly; investment costs greater then $1.7 million and annual costs greater than $0.97 million are projected for a six line production plant. This option is not considered as the basis for NSPS because of the high costs associated with this technology.

NSPS Options 4 and 5

The use of an extended multi-stage canwasher, 9-stage or its equivalent, (See Figure III-4) in water use reduction, reduces total discharge flow to 14.0 1/1000 cans. The end-of-pipe technologies for NSPS 4 and NSPS 5 (Figures XI-1 and XI-2, pages 291 and 292) are identical to the end-of-pipe technologies for NSPS 1 and NSPS 2. The incorporation of at least 3 additional stages for countercurrent rinse and recirculation of rinses reduces water use to 25 percent of the BAT value and less than 10 percent of the average raw wastewater discharge for aluminum bodies. Because new plants can be built to accommodate the extra stages without disrupting ongoing production, the use of a 9 stage canwasher as the basis for the NSPS 4 and NSPS 5 does not introduce a significant investment increase over NSPS 1 or NSPS 2 costs. In addition, a new plant can be designed to minimize or eliminate wastewater discharges from other sources (e.g. oil sumps, ion exchange regeneration, fume scrubber, and batch dumps of process solutions).

NSPS OPTION SELECTION

EPA is proposing NSPS 4 for new source performance standards. Options 1, 2 and 3 were not selected because option 4 provides greater removal of pollutants and is economically achievable. Option 5 was not selected because the addition of filtration to the small effluent flow would achieve little additional toxic pollutant reduction.

EPA selected the final NSPS because it provides a reduced discharge of all pollutants below the final BAT (compare Table XI-1 with Table X-1). The model NSPS technology is less costly than the BAT technology because the flow reduction achieved will allow the use of a smaller treatment system (see Table VIII-2).

Countercurrent Rinses - Countercurrent rinsing is a mechanism commonly encountered in metal processing operations where uncontaminated water is used for the final cleaning of an item, and water containing progressively more contamination is used to rinse the more contaminated part. The process achieves substantial efficiencies of water use and rinsing; for example, the use of a two stage countercurrent rinse to obtain a rinse ratio of about 100 can reduce water usage by a factor of approximately 10 from that needed for a single stage rinse to achieve the same level of product cleanliness. Similarly, a three stage countercurrent rinse would reduce water usage by a factor of approximately 30 for the same rinse ratio. The theoretical basis for the water use reduction achieved by 3-stage countercurrent rinsing is presented in Section VII. (Also see Figure III-4).

Cost and Effluent Reduction Benefits of NSPS

Estimates of capital and annual costs for a new plant with one to six normal lines for NSPS-4 and NSPS-5 are presented in Table VIII-2 (page 243).

In calculating NSPS costs, EPA used the "normal line" production as derived in Section IX and estimated that a new (greenfield) plant would be a large plant containing six canmaking lines. The production from this plant was multiplied by the NSPS regulatory flow, to derive the plant flows for cost estimation. The extended multistage canwasher was estimated as the added cost for pipes, pumps and other parts. No plant production or specific construction cost is included.

The pollutant reduction benefit was derived by (a) characterizing raw wastewater and effluent from each proposed treatment system in terms of concentrations produced and production normalized discharges for each significant pollutant found; and (b) calculating the quantities removed and discharged in one year by a "normal line." Results of these calculations are presented in Table XI-2 (page 289). All pollutant parameter calculations were based on mean raw wastewater concentrations for visited plants. See Table V-8, page 50.

REGULATED POLLUTANT PARAMETERS

The Agency reviewed the wastewater concentrations from individual operations to select those pollutant parameters found most frequently and at the highest levels. In Section VI each of the toxic pollutants was evaluated and a determination was made as to whether or not to further consider them for regulation. Pollutants were not considered for regulation if they were not detected, detected at nonquantifiable levels, unique to a small number of plants, or not treatable using technologies considered. All toxic pollutants listed for further consideration are discussed in this section.

Oil and grease, TSS, and pH were selected for regulation with several toxic or non-conventional metal pollutants. In the proposed regulation, the toxic metals selected for control included all those for which the concentration in the raw wastewater was above the treatability limit.

Chromate conversion coating can be applied to aluminum surfaces and cyanide compounds are used in some conversion coating formulations applied to aluminum strip. To insure that there is no additional discharge of pollutants from conversion coating waters, chromium is regulated.

In addition to the pollutant parameters listed above, there is some amount of other toxic pollutants in the canmaking wastewaters. The Agency is using an oil and grease standard for new sources in order to control the oil soluble organics found in these wastewaters. Although a specific numeric standard for organic priority pollutants is not established, adequate control is expected to be achieved by control of the oil and grease wastes. This is projected to occur because of the slight solubility of the compounds in water and their relatively high solubility in oil. This difference in solubility will cause the organics to accumulate in and be removed with the oil (See Tables VII-12, VII-13, and VII-29, pages 180, 181, and 192).

The metals selected for specific regulation are discussed and the performance standards achieved by application of NSPS also are presented. Hexavalent chromium is not regulated specifically because it is included in total chromium. Only the trivalent form is removed by the lime and settle technology. Therefore, the hexavalent form must be reduced to meet the limitation on total chromium.

CANMAKING SUBCATEGORY NSPS

The NSPS regulatory wastewater flow for the canmaking subcategory is 14.0 l/1000 cans. This level of wastewater discharge is supported in two ways. Three plants supplied data indicating their wastewater discharge from canmaking to be equal to or less than 14.0 l/1000 cans (ID #438-14.0 l/1000 cans; ID #550-13.2 l/1000 cans and ID #557-11.33 l/1000 cans). Additionally, an examination of countercurrent cascade spray rinsing applied to canwashing clearly shows this level of wastewater discharge to be technically achievable. The NSPS regulatory flow is selected as the largest of the three exemplary flows and is therefore supported by both theory and field application.

Pollutant parameters selected for regulation for NSPS are: chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS, and pH. The end-of-pipe treatment applied to reduced flow would produce effluent concentrations of regulated pollutants equal to those shown in Section VII, Table VII-21 for precipitation and sedimentation (lime and settle) technology. pH must be maintained within the range 7.5 - 10.0 at all times.

When these concentrations are applied to the water use described above, the mass of pollutant allowed to be discharged per 1,000,000 cans produced can be calculated. Table XI-3, shows the standards derived from this calculation.

DEMONSTRATION STATUS

Each major element of the NSPS technology is demonstrated in one or more canmaking plants, however no sampled canmaking plant uses all of the NSPS technology. The NSPS model system has all the same treatment components of BAT-1 plus the application of extended multistage canwashing. Early in this study four plants were identified as having water use equivalent to the NSPS water use. A recheck of calculations revealed that an error had been made in calculations for one plant. Therefore, the water use for NSPS is supported by data from 3 plants.

Countercurrent cascade spray rinsing can achieve this level. The end-of-pipe treatment is the same as BAT plus polishing filtration. Twelve plants have the BAT end-of-pipe treatment in place and filtration equipment is in place at ten plants. NSPS technology is demonstrated in the canmaking subcategory.

TABLE XI-1
SUMMARY OF TREATMENT EFFECTIVENESS FOR NEW SOURCES
CANMAKING SUBCATEGORY

PARAMETER	RAW WASTE		NSPS-4 (PSNS-4)		NSPS-5 (PSNS-5)	
	mg/1	g/10^6 cans	mg/1	g/10^6 cans	mg/1	g/10^6 cans
FLOW 1/10^6 cans		255.80		14.00		14.00
CHROMIUM	1.006	257.33	0.08	1.12	0.07	0.98
ZINC	0.924	236.35	0.30	4.20	0.23	3.22
ALUMINUM	138.300	35377.14	1.11	15.54	0.74	10.36
FLUORIDE	16.740	4282.09	14.50	203.00	9.67	135.38
IRON	1.397	357.35	0.41	5.74	0.28	3.92
MANGANESE	1.851	473.48	0.21	2.94	0.14	1.96
PHOSPHORUS	6.060	1550.14	4.08	57.12	2.72	38.08
OIL & GREASE	6596.000	1,680,000.	10.00	140.00	4.00	56.00
TSS	471.000	120481.80	12.00	168.00	2.60	36.40
TTO	2.730	698.33	0.08	1.12	0.08	1.12

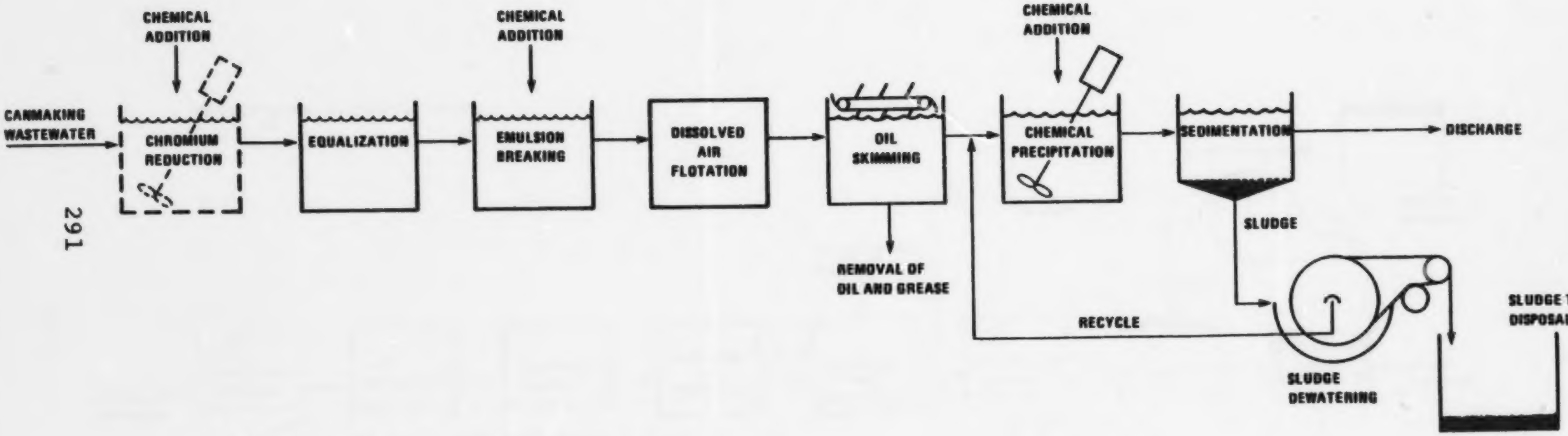
TABLE XI-2
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS
CANMAKING SUBCATEGORY - NORMAL LINE

PARAMETER	RAW WASTE	NSPS-4 (PSNS-4)		NSPS-5 (PSNS-5)	
		Removed	Discharged	Removed	Discharged
	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr
FLOW $1/10^3$cans	255.80		14.00		14.00
1/yr (10^6)	50.80		2.78		2.78
CHROMIUM	51.10	50.88	0.22	50.91	0.19
ZINC	46.93	46.10	0.83	46.29	0.63
ALUMINUM	7025.64	7022.55	3.08	7023.58	2.05
FLUORIDE	850.39	810.08	40.31	823.50	26.88
IRON	70.96	69.82	1.13	70.18	0.77
MANGANESE	94.03	93.44	0.58	93.64	0.38
PHOSPHORUS	307.84	296.50	11.34	300.28	7.56
OIL & GREASE	335076.80	335049.00	27.80	335049.00	27.80
TSS	23926.80	23893.44	33.36	23919.57	7.22
TTO	138.68	138.46	0.22	138.46	0.22
TOTAL TOXICS	236.72	235.44	1.27	235.67	1.05
TOTAL OTHER	367352.47	367234.85	117.62	367279.78	72.69
CONVENTIONALS	359003.60	358942.44	61.16	358968.57	35.02

TABLE XI-3

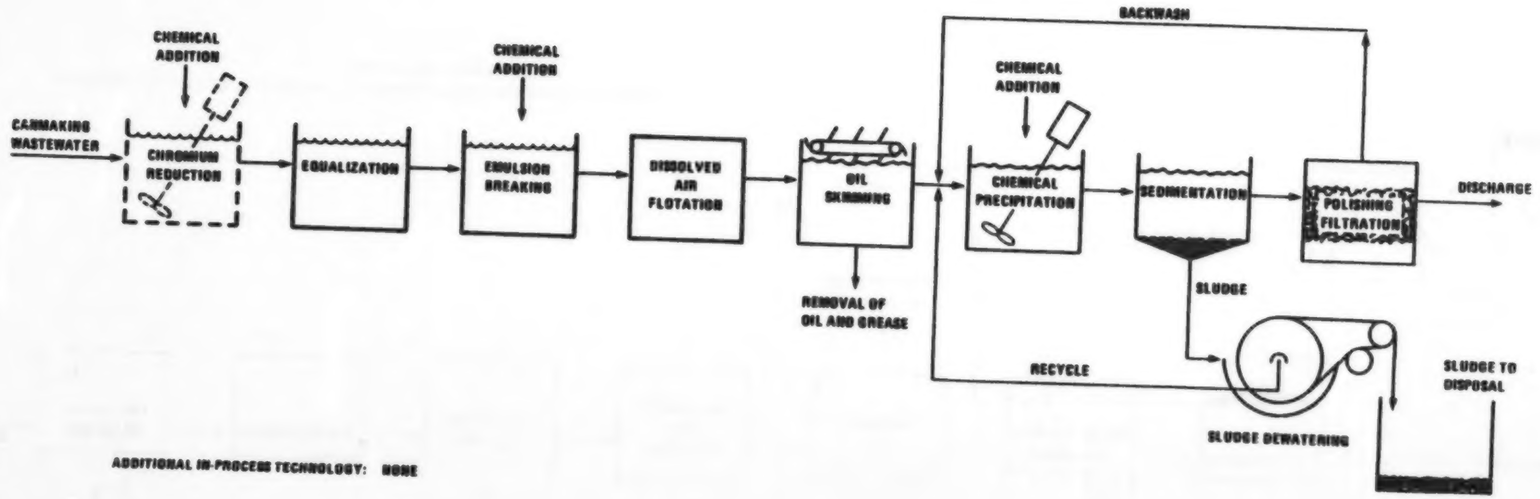
NEW SOURCE PERFORMANCE STANDARDS
CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	NSPS Effluent Limitations			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	5.88	(0.013)	2.38	(0.005)
Zn	18.62	(0.041)	7.84	(0.017)
Al	63.7	(0.140)	26.04	(0.057)
F	833.0	(1.833)	369.60	(0.813)
P	233.8	(0.514)	95.62	(0.210)
O&G	280.0	(0.616)	168.0	(0.370)
TSS	574.0	(1.263)	280.0	(0.616)
pH	within the range of 7.5 to 10 at all times			


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: WATER USE REDUCTION USING EXTENDED MULTI-STAGE CANWASHER

FIGURE XI-1. NSPS LEVEL 4 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
BACKWASH
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
POLISHING FILTRATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE XI-2. NSPS LEVEL 5 WASTEWATER TREATMENT SYSTEM

SECTION XII

PRETREATMENT

The model control technologies for pretreatment of process wastewaters from existing sources and new sources are described. An indirect discharger is defined as a facility which introduces pollutants into a publicly owned treatment works (POTW).

Pretreatment standards for existing sources (PSES) are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of publicly owned treatment works (POTW). They must be achieved within three years of promulgation. The Clean Water Act of 1977 requires pretreatment for pollutants that pass through the POTW in amounts that would violate direct discharger effluent limitations or interfere with the POTW's treatment process or chosen sludge disposal method.

The legislative history of the 1977 Act indicates that pretreatment standards are to be technology-based, analogous to the best available technology for removal of toxic pollutants. The general pretreatment regulations, which served as the framework for the pretreatment regulations, are found at 40 CFR Part 403. See 43 FR 27736 June 26, 1978, 46 FR 9404 January 28, 1981, and 47 FR 4518 February 1, 1982.

PSNS are to be issued at the same time as NSPS. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS as it considers in promulgating PSES.

Most POTW consist of primary or secondary treatment systems which are designed to treat domestic wastes. Many of the pollutants contained in canmaking wastes are not biodegradable and are therefore ineffectively treated by such systems. Furthermore, these wastes have been known to interfere with the normal operations of these systems. Problems associated with the uncontrolled release of pollutant parameters identified in canmaking process wastewaters to POTW were discussed in Section VI. The pollutant-by-pollutant discussion covered pass through, interference, and sludge usability.

EPA has generally determined there is pass through of pollutants if the percent of pollutants removed by a well operated POTW achieving secondary treatment is less than the percent removed by the BAT model treatment technology. POTW removals of the priority pollutants found in canmaking wastewater are presented in Table XII-1 (page 297). The average removal of toxic metals is about 65 percent. The BAT treatment technology removes more than 99 percent of toxic metals (see Table X-2, page 274). This difference in removal effectiveness clearly indicates pass through of toxic metals will occur unless canmaking wastewaters are adequately pretreated. Therefore, two toxic metals are regulated. As at BAT, aluminum is regulated to control toxic metals which could easily be substituted for the two which are specifically regulated. However, no removal credit can be claimed for aluminum because its is regulated to assure installation and operation of the technology.

Fluoride and phosphorus both pass through POTW. POTW remove no fluoride. POTW removal of phosphorus is 10 to 20 percent. The BAT treatment technology removes more than 80 percent of these pollutants (see Table X-2).

The Agency found small amounts of several toxic organics in canmaking wastewaters. The Agency considered and analyzed whether these pollutants should be specifically regulated.

The removal of toxic organics is about 70 percent by a secondary POTW (Table XII-1, page 297). The treatment technology for organics removal is oil skimming. The mean raw wastewater level of TTO (total toxic organics) in canmaking wastewaters is 2.73 mg/l (Table XII-2, page 298). The wastewaters from aluminum forming are similar in oil and grease loading to those from canmaking. The percent removal of organics by oil skimming from aluminum forming category wastewaters is presented in Section VII. The average removal of organics by oil skimming in aluminum forming is about 97 percent. This clearly indicates that pass through of TTO will occur unless canmaking wastewaters are adequately pretreated. Clearly there is pass through of total toxic organics, therefore TTO is regulated.

The model treatment technology system for pretreatment at existing sources (PSES) is the same as the BAT treatment system. (See Figure X-2). The model treatment system for new sources (PSNS) is the same as BDT for NSPS. (See Figure XI-1). These model technologies were selected for the reasons explained in the BAT and NSPS sections. Oil removal is included in the PSES and PSNS control technologies, benefits, and costs. The Agency believes oil and grease removal is needed to meet the total toxic organics limitations therefore, an oil and grease standard is established as an alternative monitoring pollutant.

For PSES and PSNS, the toxic metals which intefere with, pass through or prevent sludge utilization for food crops must be removed before discharge to the POTW. PSES and PSNS includes hexavalent chromium reduction to render the chromium removable by precipitation and sedimentation and cyanide removal to prevent complexing of toxic metals that hinder further treatment. Toxic metals are removed by pH adjustment and settling for PSES and PSNS. Flow reduction measures (countercurrent rinses of different effectiveness) for PSNS and NSPS are retained to provide minimum mass discharge of toxic pollutants.

Industry Cost and Effluent Reduction of Treatment Options

PSES Options 0, 1, 2, amd 3 are parallel to BPT, and BAT Options 1, 2, and 3, respectively. Also, PSNS Options are parallel to the NSPS Options. Estimates of capital and annual costs for BAT-PSES option and NSPS-PSNS options were prepared for each subcategory as an aid to choosing the best options. Results for BAT-PSES are presented in Table X-5 and results for NSPS-PSNS are presented in Table VIII-2.

PSES pollutant reduction benfits were derived from the normal line benefits and the number of normal lines reported by indirect dischargers. The pollutant reduction benefits for a normal line were presented in Table X-2. Treatment performance for the subcategory is presented in Table XII-3 (pages 299). All pollutant parameter calculations were based on mean raw wastewater concentrations for visited plants (Table V-8, page 50). The term "toxic organics" refers to toxic organics listed in Table XII-2 (page 298).

Regulated Pollutant Parameters

The Agency reviewed the canmaking wastewater concentrations, the BAT model treatment technology removals, and the POTW removals of major toxic pollutants found in canmaking wastewaters to select the pollutants for regulation. The pollutants to be regulated are the same for the subcategory as were selected for BAT except that TTO or the alternative monitoring pollutant, oil and grease is added. Toxic metals and toxic organics are regulated to prevent pass through. Conventionals are not regulated for themselves because POTW remove these pollutant parameters. Fluoride and phosphorus are non-conventional pollutant parameters which pass through POTW.

PRETREATMENT STANDARDS

Mass based limitations are set forth below (Tables XII-4 and XII-5 pages 300 and 301). The mass based limitations are the only method of designating pretreatment standards since the water use reductions at PSES and PSNS are major features of the treatment and control system. Only mass-based limits will assure the implementation of flow reduction and the consequent reduction of the quantity of pollutants discharged. Therefore, to regulate concentrations is not adequate.

The derivation of standards is explained in Section IX. The mean water use at PSES is equal to the mean water use at BAT (57.43 l/1000 cans) and its derivation is presented in Section X. For PSNS, the calculation is the same as NSPS. The mean water use at PSNS which is equal to the mean water use at NSPS is 14.0 l/1000 cans.

DEMONSTRATION STATUS

Since the model treatment technologies for PSES and PSNS are the same as BAT and NSPS, respectively, the demonstration status is presented in Sections X and XI.

TABLE XII-1

POTW REMOVALS OF THE PRIORITY POLLUTANTS FOUND IN CANMAKING WASTEWATER

	Pollutant	Percent Removal by Secondary POTW
11	1,1,1-Trichloroethane	87
29	1,1-Dichloroethylene	Not Available
44	Methylene Chloride	58
66	Bis (2-ethylhexyl) phthalate	62
67	Butyl-benzyl phthalate	59
68	Di-n-butylphthalate	48
86	Toluene	90
119	Chromium	65
128	Zinc	65

NOTE: These data compiled from Fate of Priority Pollutants in Publicly Owned Treatment Works, USEPA, EPA No. 440/1-80-301, October 1980; and Determine National Removal Credits For Selected Pollutants for Publicly Owned Treatment Works, EPA No. 440/82-008, September 1982.

TABLE XII-2

TOXIC ORGANICS COMPRISING TTO

	Pollutant	Mean Raw Waste Concentrations (mg/ℓ)
11	1,1,1-Trichloroethane	0.561
29	1,1-Dichloroethylene	0.093
44	Methylene Chloride	0.022
66	Bis (2-ethylhexyl) phthalate	1.55
67	Butyl-benzyl phthalate	0.022
68	Di-n-butylphthalate	0.464
86	Toluene	0.016
	TOTAL	2.728

TABLE XII-3
TREATMENT PERFORMANCE - INDIRECT DISCHARGERS
CANMAKING SUBCATEGORY

PARAMETER	RAW WASTE	PSES 0		PSES 1		PSES 2		PSES 3	
		Removed	Discharged	Removed	Discharged	Removed	Discharged	Removed	Discharged
	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr	kg/yr
FLOW 1/10^3 cans	255.80		176.70		57.40		57.40		57.40
1/yr (10^6)	10360.		7160.		2326.		2326.		2326.
CHROMIUM	10425.37	9852.54	572.83	10239.33	186.04	10262.58	162.79	10262.89	162.79
ZINC	9575.59	7427.47	2148.12	8877.91	697.68	9040.70	534.88	9040.70	534.88
ALUMINUM	1,430,000.	1,420,000.	7948.04	1,430,000.	2581.41	1,430,000.	1720.94	1,430,000.	1720.94
FLUORIDE	173479.96	69654.16	103825.80	139758.76	33721.20	150991.41	22488.55	150991.41	22488.55
IRON	14477.39	11541.62	2935.76	13523.89	953.49	13826.22	651.16	13826.22	651.16
MANGANESE	19182.28	17678.59	1503.68	18693.90	488.37	18856.69	325.58	18856.69	325.58
PHOSPHORUS	62800.99	33586.56	29214.43	53312.54	9488.44	56475.36	6325.63	56475.36	6325.63
OIL & GREASE	68,300,000.	68,200,000.	71604.00	68,300,000.	23256.00	68,300,000.	23256.00	68,300,000.	9302.40
TSS	4,880,000.	4,790,000.	85924.80	4,850,000.	27907.20	4,870,000.	6046.56	4,870,000.	6046.56
TTO	28291.53	27718.70	572.83	28105.48	186.04	28105.48	186.04	28105.48	186.04
TOTAL TOXICS	48292.51	44998.72	3293.78	47222.73	1069.77	47408.78	883.72	47408.78	883.72
TOTAL OTHER	74,900,000.	74,600,000.	302956.52	74,800,000.	98396.13	74,800,000.	60814.44	74,800,000.	46860.84
CONVENTIONALS	73,200,000.	73,000,000.	157528.80	73,100,000.	51163.20	73,200.000.	29302.56	73,200,000.	15348.96

TABLE XII-4

PRETREATMENT STANDARDS FOR EXISTING SOURCES CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	PSES Effluent Limitations			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	24.10	(0.053)	9.75	(0.021)
Zn	76.34	(0.167)	32.14	(0.070)
Al	261.17	(0.574)	106.76	(0.234)
F	3415.30	(7.513)	1515.36	(3.333)
P	958.58	(2.108)	392.04	(0.862)
TTO	18.36	(0.040)	8.61	(0.009)
O&G (for alternate monitoring)	2353.	(5.177)	1148.0	(2.526)

TABLE XII-5

PRETREATMENT STANDARDS FOR NEW SOURCES CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	PSNS			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Cr	5.88	(0.013)	2.38	(0.005)
Zn	18.62	(0.041)	7.84	(0.017)
Al	63.7	(0.140)	26.04	(0.057)
F	833.0	(1.833)	369.60	(0.813)
P	233.8	(0.514)	95.62	(0.210)
TTO	4.48	(0.010)	2.10	(0.005)
O&G (for alternate monitoring)	280.0	(0.616)	168.0	(0.370)

SECTION XIII

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

In 1977, Congress amended the Clean Water Act (the Act) to include section 304(b). This provision requires EPA to establish best conventional pollutant control technology (BCT) effluent limitations to be determined by an analysis of: the reasonableness of the relationship between the costs of attaining a reduction in effluents and the effluent reduction benefits derived; and the comparison of the cost and level of reduction of such pollutants from the discharge of publicly owned treatment works to the cost and level of reduction of such pollutants from a class or category of industrial sources.

BCT is not an additional effluent limitation for industrial dischargers, but rather replaces "best available technology economically achievable" (BAT) effluent limitations for the control of conventional pollutants. Effluent limitations representing BCT may not be less stringent than limitations representing "best practicable control technology currently available" (BPT).

Section 304(a) of the Act specifies that conventional pollutants include, but are not limtied to, biochemical oxygen demanding materials (BOD_5), total suspended solids (TSS), fecal coliform, and pH. The Agency has also designated oil and grease as a conventional pollutant (44 FR 44501, July 30, 1979).

In developing the methodology for the 1979 regulation, EPA was guided both by the statutory language of Section 304(b) and by Congress' underlying objectives in establishing BCT. Congress was concerned that requirements for the control of conventional pollutants beyond BPT were unreasonably expensive in some cases. Accordingly, Congress required that a special "cost reasonableness comparison" be applied before establishing BCT limitations at a level more stringent than BPT. The core of the Agency's BCT methodology was a comparison of the costs of removing additional mass of conventional pollutants for industry with comparable costs of removal for an average-sized publicly owned treatment works (POTW).

The BCT methodology was challenged in the U.S. Court of Appeals for the Fourth Circuit. On July 28, 1981, the Court issued its decision, upholding the methodology EPA had developed for the POTW cost-comparison test. American Paper Institute v. EPA, 660 F2d 954 (4th Cir., 1981). However, since EPA had recently informed the court that significant statistical errors had been found in its calculation of the POTW test, the Court directed the Agency to correct the errors.

The Court also held that the Act requires EPA to consider two "reasonableness" tests as part of the BCT methodology; an industry cost-effectiveness test and a POTW cost comparison test. Because EPA had only developed the latter test, the Court remanded the regulations and ordered EPA to develop and implement an industry cost-effectiveness test that compares the industry's costs of attaining a reduction in effluents with the effluent reduction benefits derived.

In response to the court remand, EPA has developed an industry cost-effectiveness test and corrected the statistical errors in its prior calculation of the POTW test. EPA has generally reevaluated the BCT methodology in response to a March 15, 1981 directive from the Presidential Task Force on Regulatory Relief and comments by the Council on Wage and Price Stability. Based on this review, EPA has determined that with the exception of one minor change the POTW cost-comparison methodology promulgated in 1979 and upheld by the Court of Appeals is still the preferred approach. This new and revised BCT methodology was proposed October 29, 1982 (49 FR 49176).

The methodology as proposed consists of two parts: a POTW test and an industry cost-effectiveness test. The POTW test is passed if the incremental cost per pound of conventional pollutant removed in going from BPT to BCT is less than $.27 per pound in 1976 dollars. This figure is indexed to other years to account for inflation and is $0.36 in 1981 dollars. The industry test is passed if this same incremental cost per pound is less than 143 percent of the incremental cost per pound associated with achieving BPT. Both tests must be passed for a BCT limitation more stringent than BPT to be established.

The POTW Cost Test

To make the POTW cost test it is necessary to calculate the annual incremental cost to remove a mass unit of conventional pollutants beyond BPT. This incremental cost is calculated as:

[(Candidate BCT annual cost) - (BPT annual costs)] ÷
[(Candidate BCT conventional pollutants removed) - (BPT
  conventional pollutants removed)]

For the canmaking subcategory the incremental cost of removing conventional pollutants by a BCT equivalent to BAT above BPT is:

$$\frac{420,000 - 451,900}{(7,175,056 - 7,164,628) \times 2.2} = (-)\ \$1.39/\text{lb}$$

The negative cost per pound removed is caused by the lower cost of end-of-pipe treatment at BCT. The reduced wastewater volume to be treated at BCT causes this reduced cost. When this cost is compared to the benchmark of $0.31 per pound the BCT obviously passes the POTW test.

The Industry Cost Test

This cost-effectiveness test compares the costs to industry and the effluent reduction benefits achieved in going from BPT to BCT. This comparison is accomplished by relating the ratio of the cost per unit mass of conventional pollutant removed going from BPT to BCT to the cost per unit mass of conventional pollutant removed by BPT to the benchmark ratio of 1.43. This ratio is calculated as:

$$\frac{\text{Total annual cost/pound removed (BPT to BCT)}}{\text{Total annual cost/pound removed (pre BPT to BPT)}}$$

For the canmaking subcategory the BCT cost ratio is:

$$\frac{\$31{,}900 \div (-)\ 22{,}900}{\$420{,}000 \div 7{,}175{,}000 \times 2.2} = (-)\ \frac{1.39}{0.0266} = (-)\ 52.3$$

The negative cost ratio is clearly less than the benchmark ratio of 1.43 and the BCT passes the industry cost test.

BCT Effluent Limitations

The effluent concentrations attainable through the application of BCT technology are the same as for BAT and are shown under L and S in Table VII-23. The mass discharge limitations for the conventional pollutants are calculated as the product of the BAT flow detailed in Section X and the appropriate concentration value and are presented in Table XIII-1, page 306.

TABLE XIII-1

BEST CONVENTIONAL TREATMENT EFFLUENT LIMITATIONS CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	Maximum for any one day	Maximum for monthly average
	g (lbs)/1,000,000 cans manufactured	
O&G	1148.0 (2.526)	668.8 (1.515)
TSS	2353.4 (5.177)	1148.0 (2.526)
pH	Within the range of 7.5 to 10 at all times	

SECTION XIV

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SECTION XV

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Parker Company:

Mr. Michael Quinn, Mr. Walter Cavanaugh, Mr. James Maurer,
Mr. John Scalise
Division of Oxy Metals Industries
P. O. Box 201
Detroit, MI 45220

Amchem Corporation:
Lester Steinbrecker
Metals Research Division
Brookside Avenue
Ambler, PA 19002

Diamond Shamrock
Metal Coatings Division
P. O. Box 127
Chardon, OH 44024

Wyandotte Chemical:
Mr. Alexander W. Kennedy
Mr. Gary Van Ve Streek
Wyandotte, MI

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SECTION XVI

GLOSSARY

Accumulation - In reference to biological systems, is the concentration which collects in a tissue or organism which does not disappear with time.

Acidity - The quantitative capacity of aqueous media to react with hydroxyl ions.

Acidulated Rinse - See Sealing Rinse

Act - The Federal Water Pollution Control Act (P.L. 92-500) as amended by the Clean Water Act of 1977 (P.L. 95-217).

Activator - A material that enhances the chemical or physical change when treating the metal surface.

Adsorption - The adhesion of an extremely thin layer of molecules of a gas or liquid to the surface of the solid or liquid with which they are in contact.

Agency - The U.S. Environmental Protection Agency.

Algicide - Chemical used in the control of phytoplankton (algae) in water.

Alkalinity - The quantitative capacity of aqueous media to react with hydrogen ions.

Aluminum Basis Material - Means aluminum and aluminum alloys which are processed in canmaking.

Anionic Surfactant - An ionic type of surface-active substance that has been widely used in cleaning products. The hydrophilic group of these surfactants carries a negative charge in the washing solution.

Anodizing - An electrochemical process of controlled aluminum oxidation producing a hard, transparent oxide up to several mils in thickness.

Area Processed - See Processed Area.

Backwashing - The process of cleaning a filter or ion exchange column by reversing the flow of water.

Baffles - Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water or sewage to (1) check or effect a more uniform distribution of velocities; (2) absorb energy; (3) divert, guide, or agitate the liquids; or (4) check eddy currents.

Basis Material or Metal - That substance of which the cans are made and that receives the coating and the treatments in preparation of coating.

BAT - The best available technology economically achievable under Section 304(b)(2)(B) of the Act

BCT - The best conventional pollutant control technology, under Section 304(b)(4) of the Act

BDT - The best available demonstrated control technology processes, operating methods, or other alternatives, including where practicable, a standard permitting no discharge of pollutants under Section 306(a)(1) of the Act.

Biochemical Oxygen Demand (BOD) - (1) The quantity of oxygen required for the biological and chemical oxidation of waterborne substances under conditions of test used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) Standard test used in assessing wastewater strength.

Biodegradable - The part of organic matter which can be oxidized by bioprocesses, e.g., biodegradable detergents, food wastes, animal manure, etc.

Biological Wastewater Treatment - Forms of wastewater treatment in which bacteria or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present.

BMP - Best management practices under Section 304(e) of the Act

Bodymaker - The machine for drawing, or drawing and ironing two-piece can bodies.

BPT - The best practicable control technology currently available under Section 304(b)(1) of the Act.

Buffer - Any of certain combinations of chemicals used to stabilize the pH values or alkalinities of solutions.

Cake - The material resulting from drying or dewatering sludge.

Calibration - The determination, checking, or rectifying of the graduation of any instrument giving quantitative measurements.

Canmaking - The manufacturing operations used to produce various shaped metal containers subsequently used for storing foods, beverages, and other products.

Captive Operation - A manufacturing operation carried out in a facility to support other manufacturing, fabrication, or assembly operations.

Carcinogenic - Referring to the ability of a substance to produce or incite cancer.

Central Treatment Facility - Treatment plant which co-treats process wastewaters from more than one manufacturing operation or cotreats process wastewaters with noncontact cooling water, or with non-process wastewaters, miscellaneous runoff, etc.).

Chemical Coagulation - The destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical. The amount of oxygen expressed in parts per million consumed under specific conditions in the oxidation of the organic and oxidizable inorganic matter contained in an industrial wastewater corrected for the influence of chlorides.

Chemical Oxygen Demand (COD) - (1) A test based on the fact that all organic compounds, with few exceptions, can be oxidized to carbon dioxide and water by the action of strong oxidizing agents under acid conditions. Organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances. One of the chief limitations is its ability to differentiate between biologically oxidizable and biologically inert organic matter. The major advantage of this test is the short time required for evaluation (2 hrs). (2) The amount of oxygen required for the chemical oxidation of organics in a liquid.

Chemical Oxidation - A wastewater treatment in which a pollutant is oxidized.

Chemical Precipitation - Precipitation induced by addition of chemicals.

Chlorination - The application of chlorine to water or wastewater generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

Chromate Conversion Coating - A process whereby an aqueous acidified chromate solution consisting mostly of chromic acid and water soluble salts of chromic acid together with various catalysts or activators (such as cyanide) is applied to the coil.

Chromium Process Controller - A device used to maintain a desirable and constant hexavalent chromium concentration.

Clarification - The removal of suspended solids from wastewater.

Cleaning - The process of removing contaminants from the surface of a coil.

Clean Water Act - The Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251 et seq.), as amended by the Clean Water Act of 1977 (Public Law 95-217)

Colloids - A finely divided dispersion of one material called the "dispersed phase" (solid) in another material which is called the "dispersion medium" (liquid). Normally negatively charged.

Compatible Pollutant - A specific substance in a waste stream which alone can create a potential pollution problem, yet is used to the advantage of a certain treatment process when combined with other wastes.

Composite - A combination of individual samples of water or wastewater taken at selected intervals and streams and mixed in proportion to flow or time to minimize the effect of the variability of an individual sample.

Concentration Factor - Refers to the biological concentration factor which is the ratio of the concentration within the tissue or organism to the concentration outside the tissue or organism.

Concentration, Hydrogen Ion - The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithm of the reciprocal of the hydrogen ion concentration.

Contamination - A general term signifying the introduction of microorganisms, chemicals, wastes or sewage which renders the material or solution unfit for its intended use.

Contractor Removal - The disposal of oils, spent solutions, or sludge by means of a scavenger service.

Conversion Coating - The process of applying a chromate, phosphate, complex oxide or other similar protective coating to a metal surface.

Cooling Tower - A device used to cool water used in the manufacturing processes before returning the water for reuse.

Cupping - Process whereby a flat sheet of metal is formed into a cup by means of a die punch operation (a cupper).

Degreasing - The process of removing grease and oil from the surface of the material.

Deionized Water - Water from which dissolved impurities (in the form of free ions) have been removed to reduce its electrical conducting properties and the potential for contamination of the manufacturing process.

Dewatering - A process whereby water is removed from sludge.

Die - Part on a machine that punches shaped holes in, cuts, or forms sheet metal, cardboard, or other stock.

Direct Discharger - A facility which discharges or may discharge pollutants into waters of the United States.

Dissolved Solids - Theoretically the anhydrous residues of the dissolved constituents in water. Actually the term is defined by the method used in determination. In water and wastewater treatment, the Standard Methods tests are used.

Dragout - The solution that adheres to the can and is carried past the edge of the treatment tank.

Drawing - A process where a sheet of metal is pushed into a mold or die by a solid piece of metal (punch), thus flowing over the punch to form a cup.

Draw-redraw - Process in which a second drawing step follows an initial drawing to form a deeper cup.

Drying Beds - Areas for dewatering of sludge by evaporation and seepage.

Dump - The discharge of process waters not usually discharged for maintenance, depletion of chemicals, etc.

Effluent - The wastewaters which are discharged to surface waters, directly or indirectly.

Emergency Procedures - The various special procedures necessary to protect the environment from wastewater treatment plant failures due to power outages, chemical spills, equipment failures, major storms and floods, etc.

Emulsion Breaking - Decreasing the stability of dispersion of one liquid in another.

End-of-Pipe Treatment - The reduction and/or removal of pollutants by chemical treatment just prior to actual discharge.

Equalization - The process whereby waste streams from different sources varying in pH, chemical consitutents, and flow rates are collected in a common container. The effluent stream from this equalization tank will have a fairly constant flow and pH level, and will contain a homogeneous chemical mixture.

Extrusion - Process of shaping by forcing basis material through a die.

Feeder, Chemical - A mechanical device for applying chemicals to water and sewage at a rate controlled manually or automatically by the rate of flow.

Flanging - The forming of a protruding rim or collar on the end of the can body to allow attachment of the end.

Float Gauge - A device for measuring the elevation of the surface of a liquid, the actuating element of which is a buoyant float that rests on the surface of the liquid and rises or falls with it. The elevation of the surface is measured by a chain or tape attached to the float.

Floc - A very fine, fluffy mass formed by the aggregation of fine suspended particles.

Flocculator - An apparatus designed for the formation of floc in water or sewage.

Flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

Flow-Proportioned Sample - A sampled stream whose pollutants are apportioned to contributing streams in proportion to the flow rates of the contributing streams.

Grab Sample - A single sample of wastewater taken at neither set time nor flow.

Grease - In wastewater, a group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oil, and certain other nonfatty materials. The type of solvent and method used for extraction should be stated for quantification.

Hardness - A characteristic of water, imparted by salts of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides, and nitrates that cause curdling of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminum, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate.

Heavy Metals - A general name given to the ions of metallic elements such as copper, zinc, chromium, and nickel.

Holding Tank - A reservoir to contain preparation materials so as to be ready for immediate service.

Indirect Discharger - A facility which introduces or may introduce pollutants into a publicly owned treatment works.

Industrial Wastes - The wastes used directly or indirectly in industrial processes as distinct from domestic or sanitary wastes.

In-Process Control Technology - The regulation and conservation of chemicals and rinse water throughout the operations as opposed to end-of-pipe treatment.

Ion Exchange - A reversible chemical reaction between a solid (ion exchanger) and a fluid (usually a water solution) by means of which ions may be interchanged from one substance to another. The superficial physical structure of the solid is not affected.

Ironing - A process where the side walls of a drawn cup are pressed against the punch, making them thinner and longer, and creating a deeper can of larger volume.

Lagoon - A man-made pond or lake for holding wastewater for the removal of suspended solids. Lagoons are also used as retention ponds.

Landfill - An approved site for dumping of waste solids.

Lime - Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite).

Limiting Orifice - A device that limits flow by constriction to a relatively small area. A constant flow can be obtained over a wide range of upstream pressures.

Lubricant - A substance such as oil, grease, etc., used for lessening friction.

Make-Up Water - Total amount of water used by process.

Mandrel - A shaft or bar the end of which is inserted into a workpiece to hold it during machining.

Milligrams Per Liter (mg/l) - This is a weight per volume designation used in water and wastewater analysis.

Mutagenic - Referring to the ability of a substance to increase the frequency or extent of mutation.

National Pollutant Discharge Elimination System (NPDES) - The federal mechanism for regulating discharge to surface waters by means of permits. A National Pollutant Discharge Elimination System permit issued under Section 402 of the Act.

Necking - Forming of a narrower portion at the top of a can body.

Neutralization - Chemical addition of either acid or base to a solution such that the pH is adjusted to approximately 7.

Noncontact Cooling Water - Water used for cooling which does not come into direct contact with any raw material, intermediate product, waste product or finished product.

Nonionic Surfactant - A general family of surfactants so called because in solution the entire molecule remains associated. Nonionic molecules orient themselves at surfaces not by an electrical charge, but through separate grease-solubilizing and water-soluble groups within the molecule.

NPDES - National Pollutant Discharge Elimination System.

NSPS - New source performance standards under Section 306 of the Act.

Orthophosphate - An acid or salt containing phosphorus as PO_4.

Outfall - The point or location where sewage or drainage discharges from a sewer, drain, or conduit.

Paint - A liquid composition of plastic resins, pigments and solvents which is converted to a solid film after application as a thin layer by a drying or heat curing process step.

Painted Area - (Expressed in terms of square meters). The dimensional area that receives an enamel, plastic, vinyl, or laminated coating.

Palletizing - The placing of finished cans into a portable storage container prior to their being filled.

Parshall Flume - A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length. At the throat is a sill over which the flow passes as critical depth. The upper and lower heads are each measured at a definite distance from the sill. The lower head cannot be measured unless the sill is submerged more than about 67 percent.

pH - The negative of the logarithm of the hydrogen ion concentration.

pH Adjust - A means of maintaining the optimum pH through the use of chemical additives.

Phosphate Coating - In canmaking the process of forming a conversion coat on aluminum by spraying a hot solution of phosphate, containing titanium or zirconium.

Pollutant - The term "pollutant" means dredged spoil, solid wastes, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal and agricultural waste discharged into water.

Pollutant Parameters - The characteristics or constituents of a waste stream which may alter the chemical, physical, biological, radiological integrity of water.

Polyelectrolytes - Used as a coagulant or a coagulant aid in water and wastewater treatment. They are synthetic or natural polymers containing ionic constituents. They may be cationic, anionic, or nonionic.

POTW - Publicly Owned Treatment Works.

Prechlorination - (1) Chlorination of water prior to filtration. (2) Chlorination of sewage prior to treatment.

Precipitate - The solid particles formed from a liquid solution due to the saturation of the solid in the solution having been achieved.

Precipitation, Chemical - Precipitation induced by addition of chemicals.

Pretreatment - Any wastewater treatment process used to reduce pollution load partially before the wastewater is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

Printing - The technique of rolling a design on a painted strip.

Priority Pollutant - The 129 specific pollutants established by the EPA from the 65 pollutants and classes of pollutants as outlined in the consent decree of June 8, 1976.

Process Water - Any water which during manufacturing or processing, comes into direct contact with or results from the production or use of any raw materials, intermediate product, finished product, by-product, or waste product.

PSES - Pretreatment standards for existing sources of indirect discharges under Section 307(b) of the Act.

Publicly Owned Treatment Works (POTW) - A central treatment works serving a municipality.

Raw Wastewater - Plant water prior to any treatment or use.

RCRA - Resource Conservation and Recovery Act (PL 94-580) of 1976, Amendments to Solid Waste Disposal Act.

Recirculated Water - Process water which is returned as process water in the same or in a different process step.

Rectangular Weir - A weir having a notch that is rectangular in shape.

Recycled Water - Process water which is returned to the same process after treatment.

Reduction Practices - (1) Wastewater reduction practices can mean the reduction of water use to lower the volume of wastewater requiring treatment and (2) the use of chemical reduction to lower the valance state of a specific wastewater pollutant.

Reduction - The opposite of oxidation treatment wherein a reductant (chemical) is used to lower the valence state of a pollutant to a less toxic form e.g., the use of SO_2 to "reduce" hexavalent chromium to trivalent chromium in an acidic solution.

Retention Time - The retention time is equal to the volume of a tank divided by the flow rate of liquids into or out of the tank.

Rinse - Water for removal of dragout by dipping, spraying, fogging, etc.

Sanitary Sewer - A sewer that carries water or wastewater from residences, commercial buildings, industrial plants, and institutions together with minor quantities of ground, storm, and surface waters that are not admitted intentionally.

Sealing Rinse - The final rinse in the conversion coating process which contains a slight concentration of chromic acid.

Seaming - In canmaking the joining of two edges of a rolled metal blank to form a cylinder and the joining of ends or tops to can bodies.

Seamless - In canmaking refers to can bodies formed without side seams. Cans are formed by drawing of flat sheet metal into a cupped shape.

Secondary Waste Water Treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Sedimentation - Settling by gravity of matter suspended in water.

Settleable Solids - (1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour, but either settles to the bottom or floats to the top. (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in one hour.

Skimmer - A device to remove floating matter from wastewaters.

Sludge - The solids (and accompanying water and organic matter) which are separated from sewage or industrial wastewater.

Sludge Dewatering - A process used to increase the solids concentration of sludge.

Sludge Disposal - The final disposal of solid wastes.

Solvent - A liquid capable of dissolving or dispersing one or more other substances.

Spills - A chemical or material spill is an unintentional discharge of more than 10 percent of the daily usage of a regularly used substance. In the case of a rarely used (one per year or less) chemical or substance, a spill is that amount that would result in 10% added loading to the normal air, water or solids waste loadings measured as the closest equivalent pollutant.

Stamping - Forming or cutting of can tops by the application of a die.

Suspended Solids - (1) Solids that either float on the surface of, or are in suspension in water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Waste Water" and referred to as non-filterable residue.

Teratogenic - Referring to the ability of a substance to form developmental malformations and monstrosities.

Three-piece cans - Cans formed by combining a cylindrical portion and two ends. Usually, the sides are formed by wrapping a metal around a mandrel and locking the seam.

Total Cyanide - The total content of cyanide including simple and/or complex ions. In analytical terminology, total cyanide is the sum of cyanide amenable to chlorination and that which is not according to standard analytical methods.

Total Solids - The total amount of solids in a wastewater in solution and suspension.

Toxicity - Referring to the ability of a substance to cause injury to an organism through chemical activity.

Treatment Facility Effluent - Treated process wastewater before discharge.

Trimming - Removal of excess metal from the top of a shaped can body.

Turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

Two-piece cans - Cans formed by drawing a flat metal plate into a cup and attaching a top.

Viscosity - That property of a liquid paint or coating material which describes its ability to resist flow or mixing. Paint viscosity is controlled by solvent additions and its control is essential to effective roller-coater operation and uniform dry films thickness.

Waste plate - Tin plate with defects too severe to repair. It is used for making cans for products such as paint which will not be adversely affected by the defects.

Water Balance - An accounting of all water entering and leaving a unit process or operation in either a liquid or vapor form or via raw material, intermediate product, finished product, by-product, waste product, or via process leaks, so that the difference in flow between all entering and leaving streams is zero.

Water Use - The quantity of process water used in processing a specified number of cans (expressed as 1/1,000 cans)

Weir - (1) A diversion dam. (2) A device that has a crest and some containment of known geometric shape, such as a V, trapezoid, or rectangle and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening. Criteria and Standards Division, Office of Water Regulations and Division, Office of Water Regulations and Standards, U.S. EPA.